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STRATIGRAPHY OF THE HORN PLATEAU FORMATION: A MIDDLE DEVONIAN REEF, NORTHWEST TERRITORIES

by

(C) LORNE KENELM VOPNI

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
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OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

EDMONTON, ALBERTA

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FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Stratigraphy of the Horn Plateau Formation: a Middle Devonian Reef, Northwest Territories", submitted by Lorne Kenelm Vopni, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

Date Sept 30, 1969

ABSTRACT

The Horn Plateau Formation is a Middle Devonian limestone reef approximately 0.4 miles in diameter which crops out on the Interior Plains about 110 miles west of Yellowknife, Northwest Territories. This study is largely a paleontologic and petrographic examination of material collected from the outcrop and 5 core holes drilled on and near the reef.

Corals are the most important framebuilders present and crinoid ossicles contribute most to the sediment volume. Three macrofacies of this coral patch reef are recognized: 1) organic reef, an area where framebuilders grew profusely 2) reef flat, an area characterized by sand sized sediments, and 3) reef flank, an area of predominantly gravel sized sediments. It is interpreted that strongly agitated water conditions prevailed over the organic reef and reef flank macrofacies and that moderately agitated water conditions were present on the reef flat. Subdivision of the macrofacies has produced 11 microfacies of distinctive texture-composition combinations. Paleoecologic and analysis of the individual organism or group permits recognition of 7 successive biotopes from a deeper off reef position up onto the reef flat. Prevailing winds were from the northeast and it is interpreted that the Horn Plateau reef is analogous to the Recent Sahul Shelf reefs off Western Australia.

A new interpretation of the age of the Horn Plateau reef is presented as a result of the additional fauna collected. The reef is middle Givetian in age, older than previously believed, and is correlative with the middle Pine Point and upper Ramparts Formations. The controversy over the stratigraphic position of the Horn Plateau Formation is solved in that the reef "roots in" the Lonely Bay

Formation, and is overlain by the black shale of the Horn River Formation. The reef developed north of the facies front between the Horn River shale and Pine Point carbonates. It is predicted that further drilling will discover additional reefs in similar paleogeographic and stratigraphic position.

ACKNOWLEDGEMENTS

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Horn Plateau reef in foreground showing stack and pillar erosion of the organic reef macrofacies looking west - southwest from a height of approximately 150 feet.

INTRODUCTION

Horn Plateau Reef

The Horn Plateau Formation is a coral reef of Middle Devonian age. It crops out as a circular hill approximately 0.4 miles in diameter and is located 2.9 miles west of the southwest tip of Fawn Lake in the District of Mackenzie, Northwest Territories (Fig. 1). The co-ordinates of the reef are 62° 08.2'N, 117° 39'W. To date (September, 1969), this reef exposure is the only known occurrence of the Horn Plateau Formation.

In August, 1968 geological work and a coring program on the reef was conducted by Pan American Petroleum Corporation, Calgary and supervised by the writer. The purpose of this coring program was to find the vertical and lateral extent of the reef and what it "roots in", that is, the relationship of the Horn Plateau Formation to the Horn River Formation and to the Lonely Bay Formation. A total of 1455 feet of 1.6 inch diameter core was taken from 5 core-holes. These are designated as Pan Am Fawn Lake Core-hole Numbers 1 to 5 (Appendix A).

The present study is a synthesis of this field work and subsequent detailed sample examination in the laboratory. In an attempt to classify the reef, its geometry and lateral and vertical extents are discussed. Emphasis is placed on the petrographic examination and classification of the rocks in order to differentiate facies and to attempt to establish their environmental and sedimentological significance. The distribution of the fossil organisms is outlined and their paleoecology discussed in determining what particular faunal/flora assemblages existed on the reef during its growth. A comparison is made between the Horn Plateau reef and a Recent reef with respect to sediments and morphology, in order to suggest an analagous geographic situation. The age of

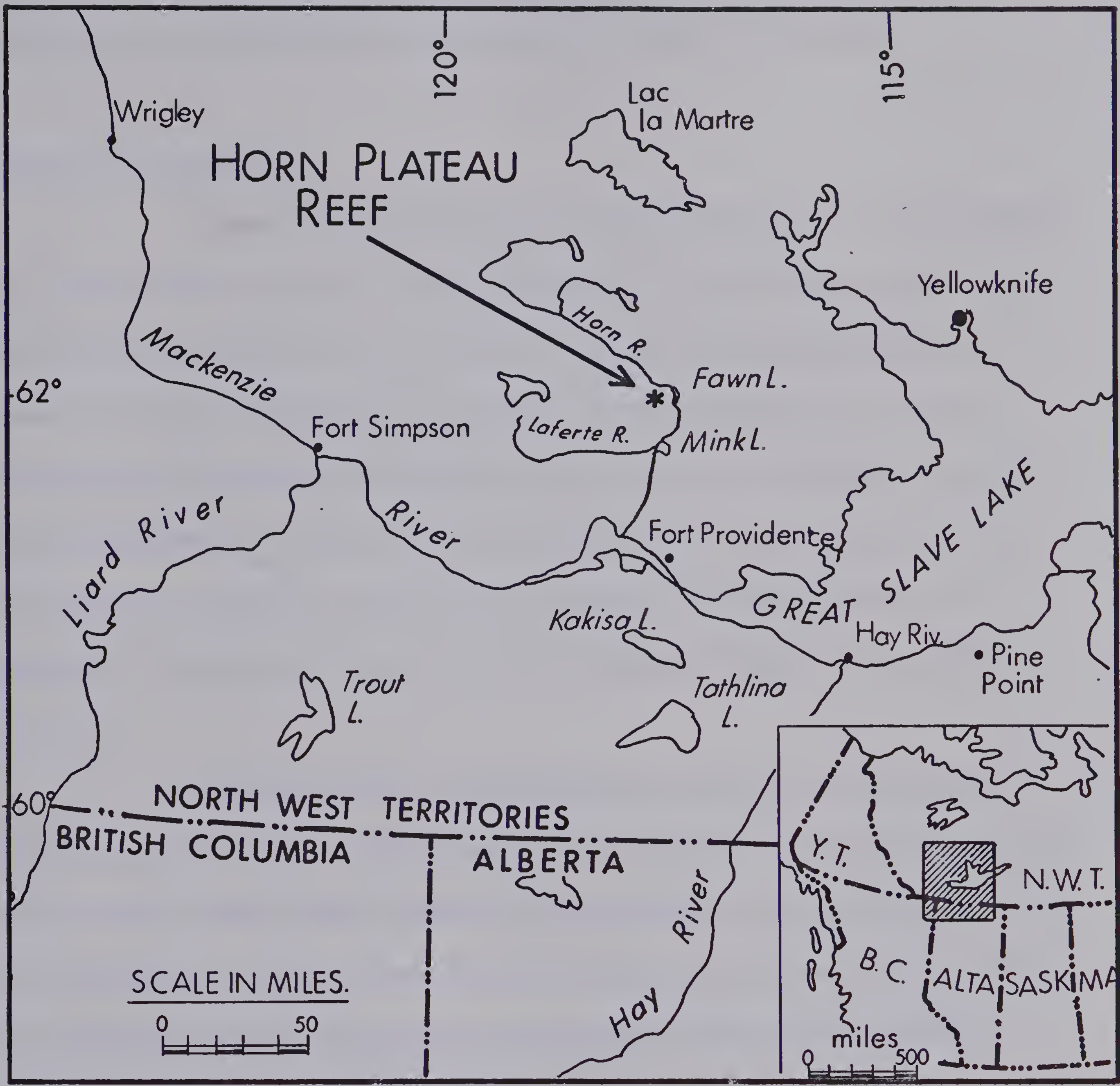


Fig. 1. Location of the Horn Plateau reef

the fauna is also re-examined to determine whether the previously assigned very late Givetian age for the Horn Plateau Formation is valid. Finally, the reef's age, facies, geological setting, paleoecology, and paleoenvironment are considered in reconstructing the geological development of the reef.

Method of Investigation

Surface work on the reef was facilitated by 20 cut-lines radiating from approximately the center of the reef (Fig. 2). These lines permitted easy plane-tabling and good outcrop control. Traverses were conducted from the center point down each line using a tape for horizontal control. Every outcrop along each traverse was examined, noting the type of lithology, type and relative abundance of fauna, and, any sedimentary structures. Representative hand samples, megafossils, and at some localities, microfossil samples were collected. The numbers between 1 and 105 in Figure 2 indicate the specific outcrops.

In the laboratory, hand samples were slabbed, polished, and etched for several seconds in 10 percent HCl. A solution of 50 percent glycerine applied to the etched surface aided in the stereoscopic microscopic study. Data were recorded on a logging format similar to that used by Klovan (1964, p. 45). Selected hand and core samples were stained with Alizarin Red S (Friedman, 1959) to determine the dolomite content.

Initially, the outcrop samples were separated into microfacies by visually grouping rocks with the same type, size, and relative abundance of skeletal grains. Where possible, 5 representative samples and at least 1 thin section from each of these microfacies were quantitatively examined by the point count method (Chayes, 1954), recording the type and size of 100 grains. Due to the abundance of granule and pebble sized grains it was necessary to use hand

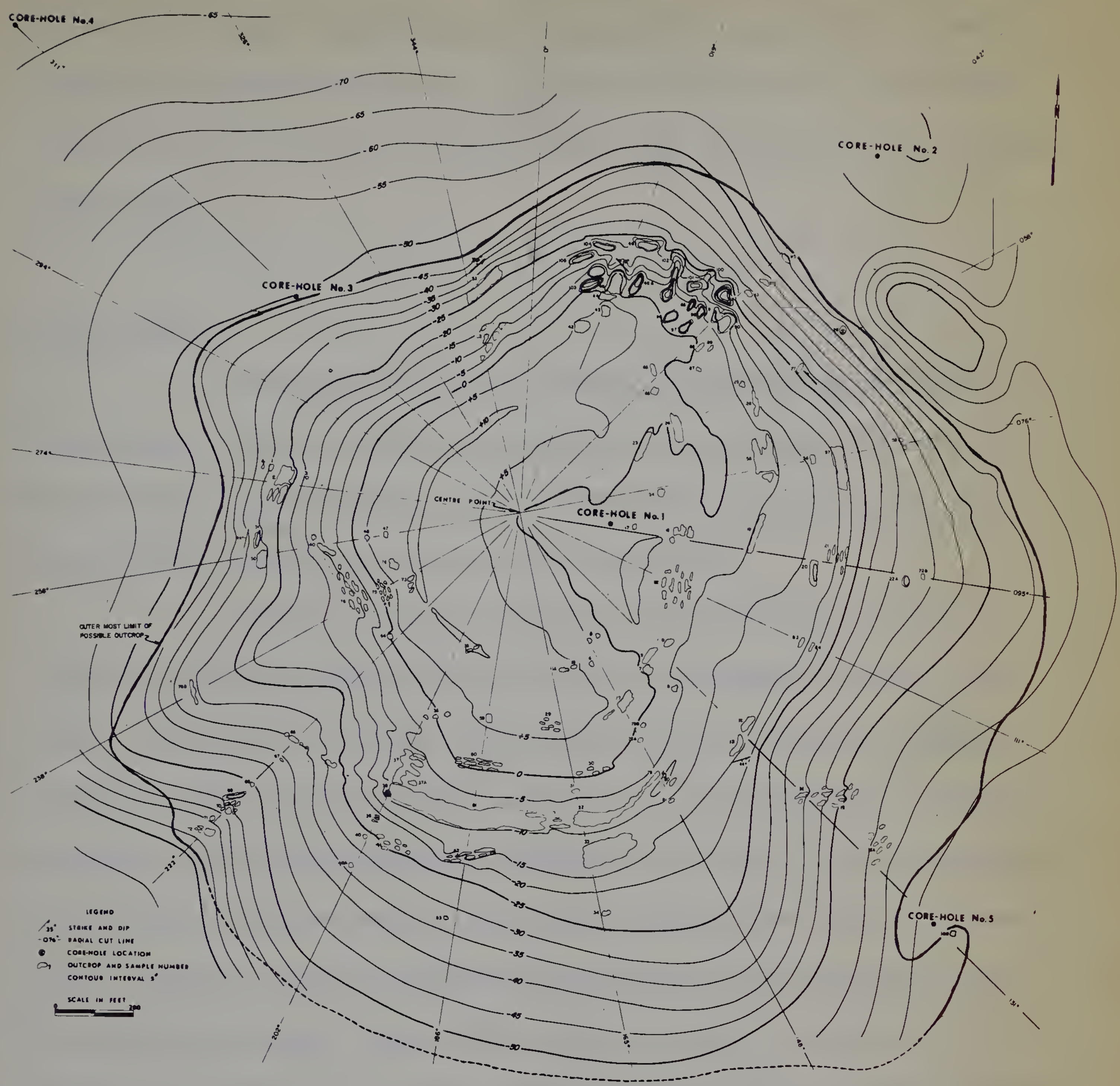


Fig. 2. Topographic and outcrop map of the Horn Plateau reef.

samples to supplement thin sections. These microfacies, which were established for the outcrop samples, were then extended to the slabbed cores.

Longitudinal and transverse polished sections were made of corals and stromatoporoids. Identification of these and other megafossils was made by reference to available collections and published illustrations. Gamma-logs of the wells within the study area were used to make cross-sections and structure contour maps.

Previous Work

Few articles have been published on the lithology and fauna of the study area. Whittaker (1922), examined the country along the Mackenzie River between Great Slave Lake and Fort Simpson and proposed the term Horn River Shale for shale that outcrops along the Horn River.

In 1957, the Geological Survey of Canada conducted a helicopter reconnaissance of 100,000 square miles of southwestern District of Mackenzie. This project was termed "Operation Mackenzie" (Douglas, 1958) and 3 pertinent papers pertaining to the study area were produced from it. Douglas and Norris (1960) described the reefal limestone (now Horn Plateau Formation), the Horn River Formation and the fossiliferous limestone (now Lonely Bay Formation). McLaren and Norris (1964) described the fauna and stratigraphy of the Horn Plateau Formation. Norris (1965) applied the names Horn Plateau Formation to the reefal limestone and Lonely Bay Formation to the fossiliferous limestone, and redefined the Horn River Formation.

Richmond (1965), in an unpublished Ph.D. thesis, studied the Paleozoic stratigraphy for the Great Slave Lake area and correlated the Horn Plateau Formation on a regional basis.

Various oil companies, namely, Shell Oil Company in 1957, Union

Oil Company in 1958, Pan American Petroleum Corporation in 1960, and Mobil Oil Company in 1966, have done reconnaissance studies on the Horn Plateau reef. These reports have been kept confidential.

For an extensive review of the regional geology the reader is referred to Norris (1965) and Richmond (1965).

Reef Terminology

The reef definitions of Klovan (1964, p. 11) have gained acceptance by many reef workers (e.g., Jenik and Lerbekmo, 1968; Langton and Chin, 1968; Leavitt, 1968) and two of his definitions are used in this study, namely:

Organic Reef – that portion of the reef which is or was built directly by organisms, and is responsible for the reef's wave resistant character.

Reef – rigid carbonate structures with vertical dimensions significantly larger than the contemporaneous sediments, composed, at least in part, of organisms able to build and maintain the structure as a topographic feature on the sea floor and potentially in the zone of wave action.

The definitions of other reef terms that will be used are:

Patch Reef – a small reef surrounded by deeper water and lacking a lagoon (Kornicker and Boyd, 1962, p. 641).

Reef Flank Deposits – reef talus, generally consisting of inclined strata deposited against the sides of an organic reef, composed mainly of fragmental material derived from the reef (*fide* Weller, 1960, p. 55).

Reef Flat – a stony expanse of dead reef rock with a flat surface. It generally becomes partly or entirely dry at low tide. Patches of sand

and debris and a few widely scattered colonies of the more hardy species of coral diversify the featureless horizontal surface of many reef flats. Shallow pools are a normal feature on some, others are crossed by irregular gullies or are riddled with pot-holes (fide Howell, 1957, p. 241).

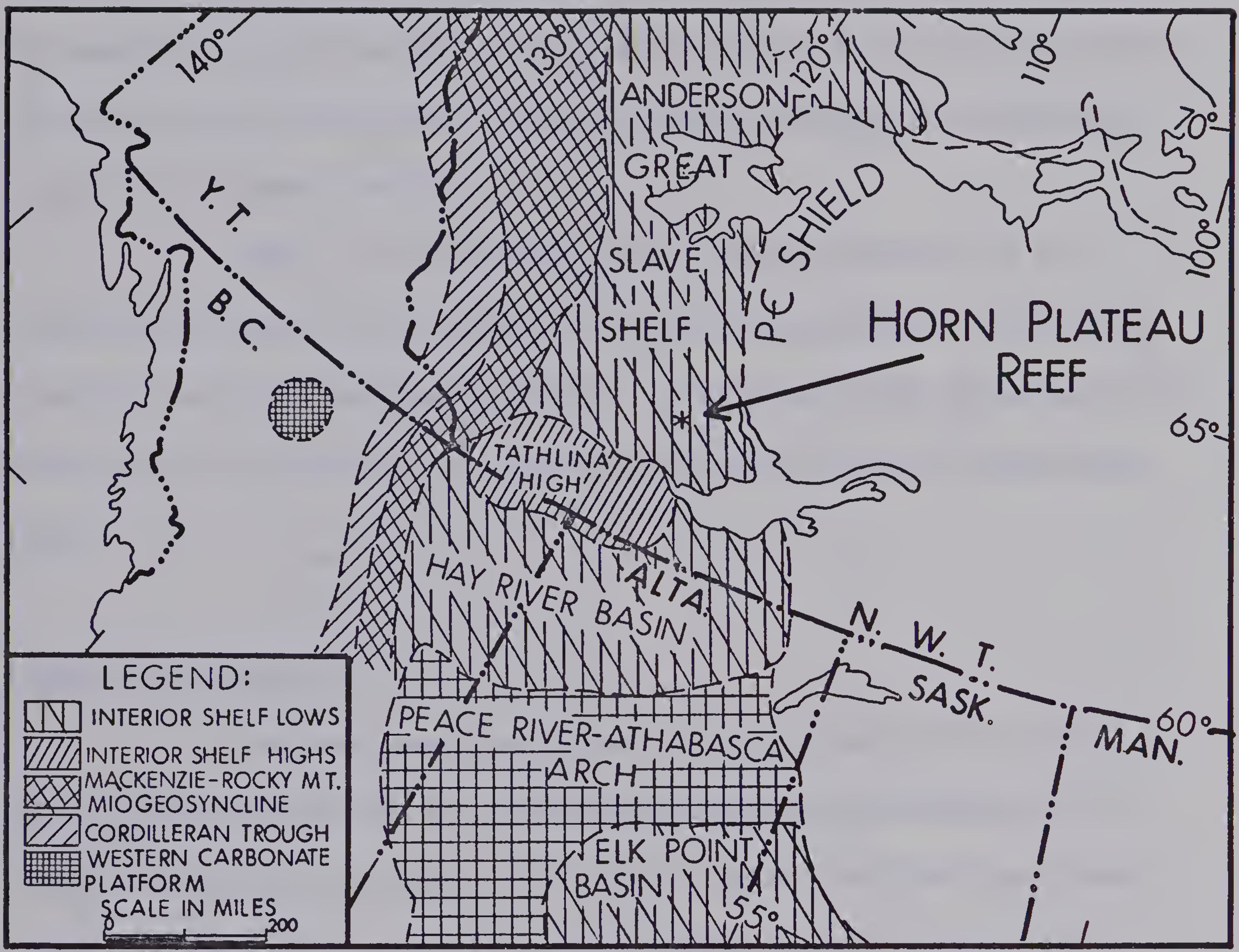
STRATIGRAPHY

Stratigraphic Setting of the Horn Plateau Formation

The name Horn Plateau Formation was proposed by Norris (1965, p. 78) for a richly fossiliferous reefal limestone body exposed on a circular hill located on the east flank of Horn Plateau. This formation corresponds to map-unit 15 of Douglas and Norris (1960). The Horn Plateau Formation is classified by the present writer as a coral patch reef.

The paleogeology of the Horn Plateau reef is illustrated in Figure 3. The reef was situated within the slowly subsiding Anderson-Great Slave Shelf (Basset and Stout, 1967). In relationship to the reef, the tectonic Tathlina Basement High was to the south, the Pre-cambrian Shield was to the east, and the Mackenzie-Rocky Mountain miogeosyncline was to the west. This paleogeological terminology differs from that used by Grayston et al (1964), as they would have the Horn Plateau reef situated within the Southern Mackenzie Basin.

The area of interest has been glaciated by the Wisconsin Laurentide ice-sheet and was covered by Glacial Lake McConnell (Craig, 1965). Strand lines of the lake can be observed in the air photographs (A 11030-167 and A 11030-168) which includes the reef. The writer's interpretation is that little erosion of the reef has taken place.



after Basset and Stout, 1967

Fig. 3. Paleogeomorphic setting at the time of development of the Horn Plateau reef.

The stratigraphic nomenclature of the Devonian formations to be discussed is shown in Table I. The nomenclature is the same as that used by Norris (1965) except that the results obtained from the Pan Am Fawn Lake Core-holes have allowed accurate delineation of certain formational boundaries. The exact stratigraphic position of the reef with respect to the underlying formations is not known because none of the core-holes penetrated the underlying evaporitic Chinchaga Formation.

Table 2 is a chart showing the regional correlation of the pertinent Horn Plateau area formations. The reef is correlative to the middle Pine Point and upper Ramparts Formations. A complete resumé of the fauna and their age will be presented in the section titled Correlation and Age Relationships.

Lonely Bay Formation

The name Lonely Bay Formation was applied by Norris (1965, p. 40) to a resistive carbonate unit conformably overlying the evaporitic Chinchaga Formation and overlain by shale and limestone of the Horn River Formation. This formation would correspond to the basal part of map-unit 13 of Douglas and Norris (1960). No type section was designated for the formation. Norris (1965, p. 42) tentatively assigned the formation to the lower Givetian.

The best exposures of the Lonely Bay Formation are along a limestone escarpment which trends west-northwest in the southern part of the Great Slave Lake region (Norris, ibid., p. 40). There it commonly consists of an aphanitic to fine-grained limestone. No reefal development of the Lonely Bay Formation exists in outcrop and the contact with the overlying Horn River Formation has not been observed (Norris, 1965, p. 41).

In the subsurface, the Lonely Bay Formation in the C.S. Laferte

AGE		HORN PLATEAU REEF AREA		
		Douglas & Norris (1960)	Norris (1965)	This Thesis
DEVONIAN	UPPER	Simpson Formation (16)	Hay River Formation	Hay River Formation
DEVONIAN	MIDDLE	Map—unit (15)	HORN PLATEAU Formation	
DEVONIAN	MIDDLE	HORN RIVER FORMATION (14)		?
DEVONIAN	MIDDLE	? Map—unit (13)	HORN RIVER FORMATION	HORN RIVER FORMATION; HORN PLATEAU FORMATION ? ?
DEVONIAN	MIDDLE	Map—unit (13)	Lonely Bay Formation	Lonely Bay Formation
DEVONIAN	MIDDLE	Map—unit (12)	Chinchaga Formation	Chinchaga Formation

TABLE I.

Formational nomenclature of the HORN PLATEAU area, Northwest Territories.

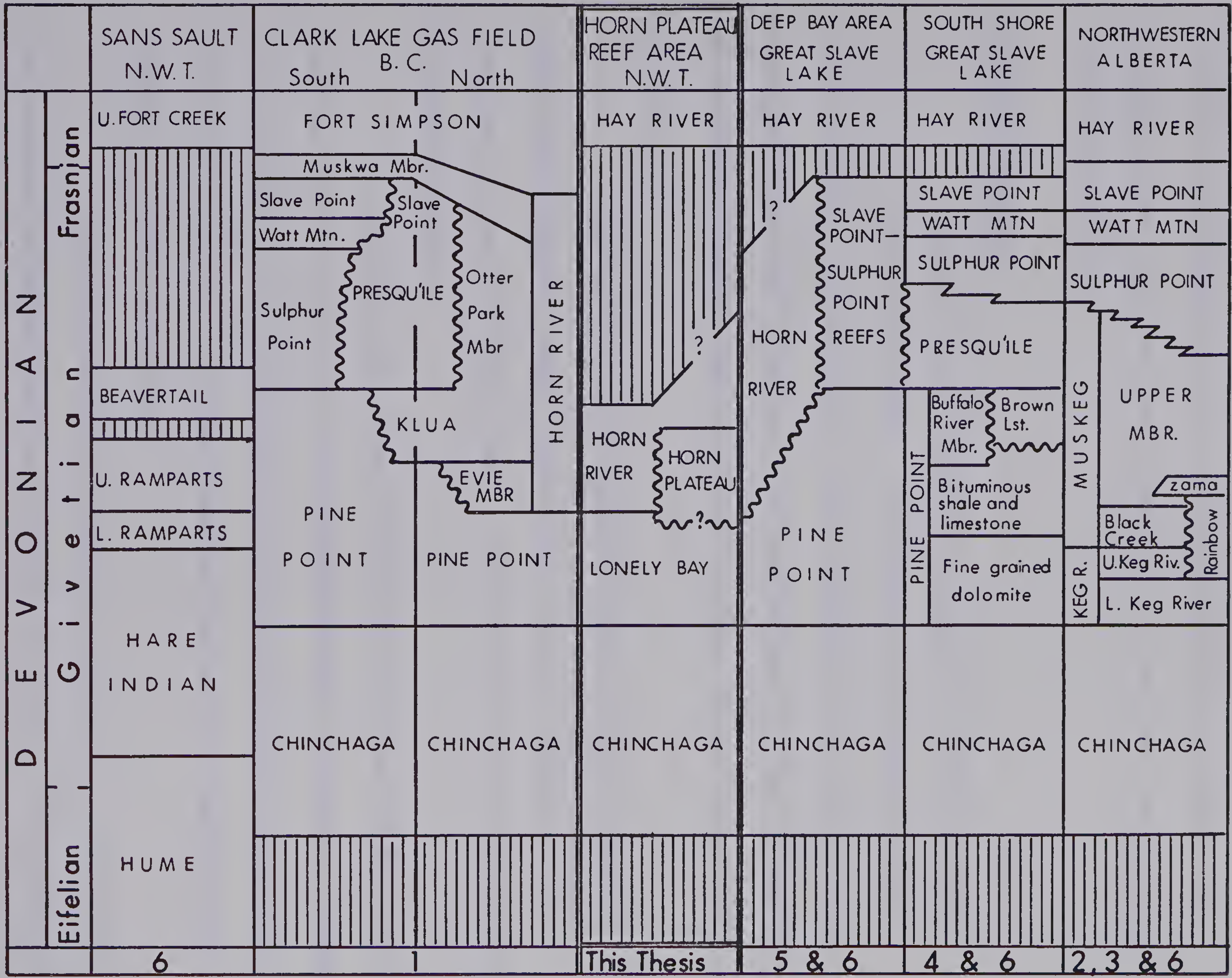


TABLE 2.

Correlation chart of Givetian formations of Western Canada. Major sources of information: 1) Gray and Kassube (1963), 2) Hriskevich (1966), 3) Mc.Camis and Griffith (1967), 4) Norris (1965), 5) Richmond (1965), 6) Warren & Stelck (1962).

River wells of the study area consists generally of a brown micritic limestone with scattered fossils throughout (J.K. Evans, pers. comm., 1969). With the available electric and gamma logs it is not possible to pick the contact of the Lonely Bay Formation and the underlying Chinchaga Formation. The description of the formational contacts from the Pan Am Fawn Lake Core-holes will be discussed later.

Horn River Formation

The name Horn River Shale was proposed by Whittaker (1922, p. 52) for the brown to black fissile, well jointed and fractured shale which he first observed on the Horn River 11 miles northwest of Fawn Lake; this shale he assigned to the Middle Devonian. He used the term Pine Point Limestone for the fossiliferous limestone that overlies the Horn River Shale at two localities on the Horn River.

Norris (1965, p. 43) redefined the term Horn River Shale to apply to a unit consisting largely of dark shales variably interbedded with limestones and gave it formational status. His definition would include Whittaker's Pine Point Limestone.

In outcrop, the exposed shale weathers into small flakes with rusty brown iron stains along the joints. The contacts between the Horn River Formation and the underlying Lonely Bay Formation, and between the Horn Plateau Formation and the "overlying" Hay River Formation have not been observed in outcrop (Norris, 1965, pp. 41 & 43).

The subsurface shale obtained from the Pan Am Fawn Lake Core-holes resembles the surface exposures; it is black to dark grey with frequent 1/16 to 1/8 inch pyrite lenses. Near the base of the Horn River Formation in the southern part of the study area there is a unit approximately 35 feet thick which

has anomalously high radioactivity. Progressing in a northeasterly direction towards the outcrop, this unit breaks up into two subunits (Fig. 4). The possibility exists that this type of lithologic behavior might be used as a clue in the search for additional reefs that probably occur in the subsurface.

Horn Plateau Formation

Figure 5 illustrates the interpreted stratigraphic relationship of the Horn Plateau reef to the underlying and overlying formations. Data from the Pan Am Fawn Lake Core-holes were used extensively in the interpretation.

In Core-hole No. 1, located near the center of the outcrop (Fig. 2), a 4 foot black, argillaceous breccia unit lies between 63 and 67 feet*. A bioclastic limestone overlies and underlies this breccia unit. The contacts of the breccia unit with the underlying and overlying limestone are at extremely steep angles, namely, 75 and 50 degrees respectively (Pl. 7, Fig. 15). The limestone on both sides of the breccia unit is similar. The writer suggests that this breccia does not represent an hiatus, but rather is a result of fracture filling. Supporting evidence of fracture filling occurs in Core-hole No. 1: firstly, at 217 feet there are argillaceous lithoclasts floating in a sparry calcite cement, which strongly suggests fracture filling (Pl. 7, Fig. 8); secondly, from 56 to 61 feet a porous crinoidal calcarenite has a vertical contact with *in situ* colonial rugose corals. This contact can best be explained as fracture filling. Paleontologic support for this interpretation of the breccia unit is given by the presence of conodonts which are considered to be younger than the brachiopod fauna from the overlying reefal outcrop unit (C.A. Polluck, pers. comm., 1969).

In Core-hole Nos. 3, 4, and 5 which were drilled "offreef", the Horn Plateau reef is overlain sharply by the Horn River Formation; the contact

* All core footages refer to depths below the surface.

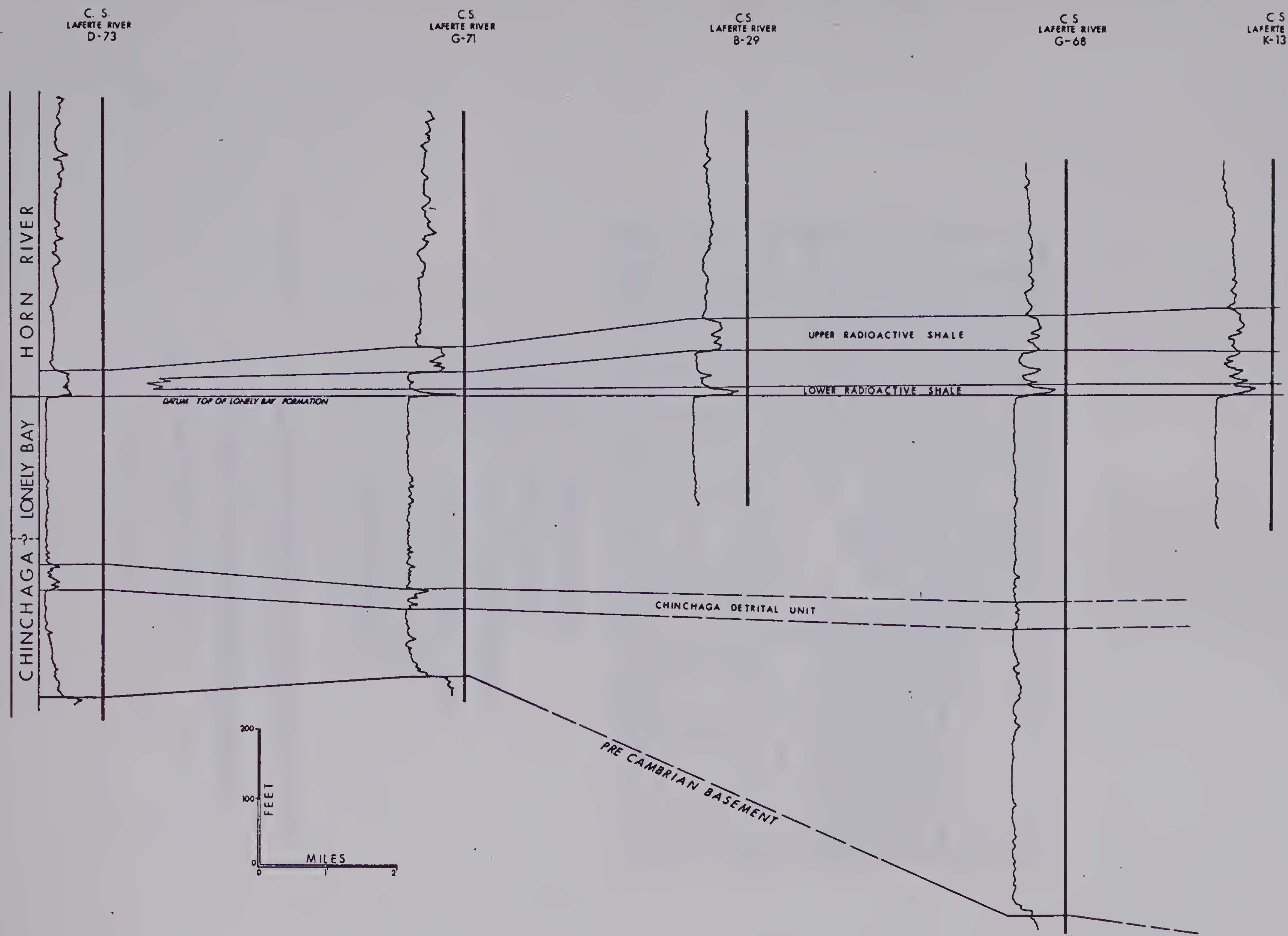


Fig. 4. Southwest to northeast stratigraphic cross section from C.S. Laferte River D-73 to C.S. Laferte River K-13 using gamma ray logs showing radioactive units in lower Horn River Formation. (For location of wells see Fig. 6).

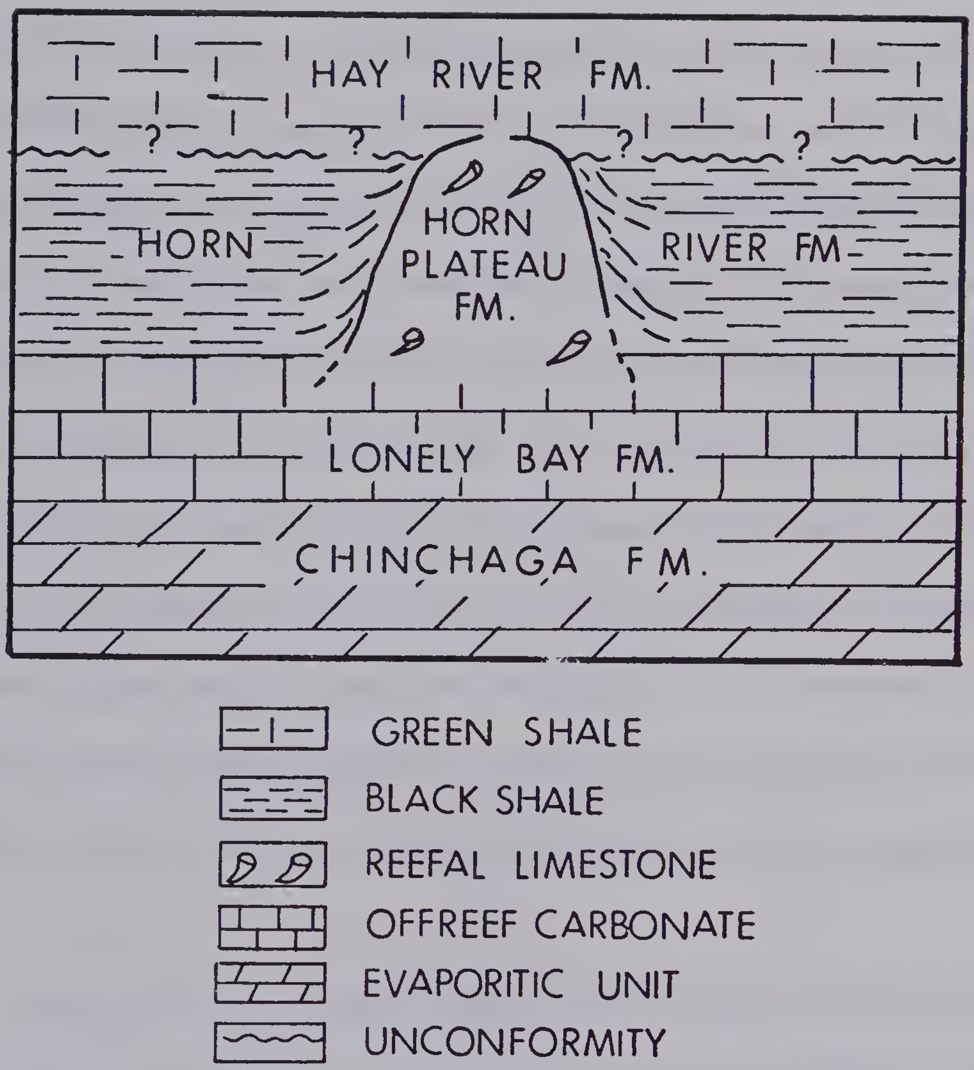


Fig. 5. Interpreted stratigraphic relationship of the Horn Plateau Formation to the underlying and overlying formations.

is gradational in Core-hole No. 2. This is the first known conclusive evidence that the Horn Plateau Formation is overlain by the Horn River shale.

The coring did not go deep enough to reveal with certainty where the Horn Plateau reef is "rooted". Norris (1965, p. 78) and Belyea and Norris (1962, p. 12) suggest that the Horn Plateau Formation overlies the Horn River Formation, and McLaren and Norris (1964) believe that the reef developed in the upper part of the Horn River Formation or the lower part of the Fort Simpson Formation but another possibility exists, namely, that the Horn Plateau reef is "rooted in" the Lonely Bay Formation. Richmond (1965, Fig. 17) illustrated this relationship but did not have the information now available to support this conclusion. The top of the Lonely Bay Formation in the vicinity of the reef should subcrop at approximately 490 feet above sea level (Fig. 6). Core-hole No. 3 penetrated a calcilutite at 484 feet above sea level and bottomed in this unit at 473 feet above sea level, thus suggesting that if any Horn River Formation does exist beneath the Horn Plateau reef, it would be relatively thin. The writer's interpretation is that the Horn Plateau reef is "rooted in" the Lonely Bay Formation. Lithologies which will be discussed in the facies analysis section support this interpretation.

The contact of the Horn Plateau reef with the overlying formation has not been observed in outcrop or in the subsurface. Norris (1965, p. 78) suggested that the Hay River Formation probably unconformably overlies the Horn Plateau Formation. The writer's interpretation is that the Horn Plateau Formation is older than Norris believed, and that the Horn River Formation could overlie the entire Horn Plateau Formation.

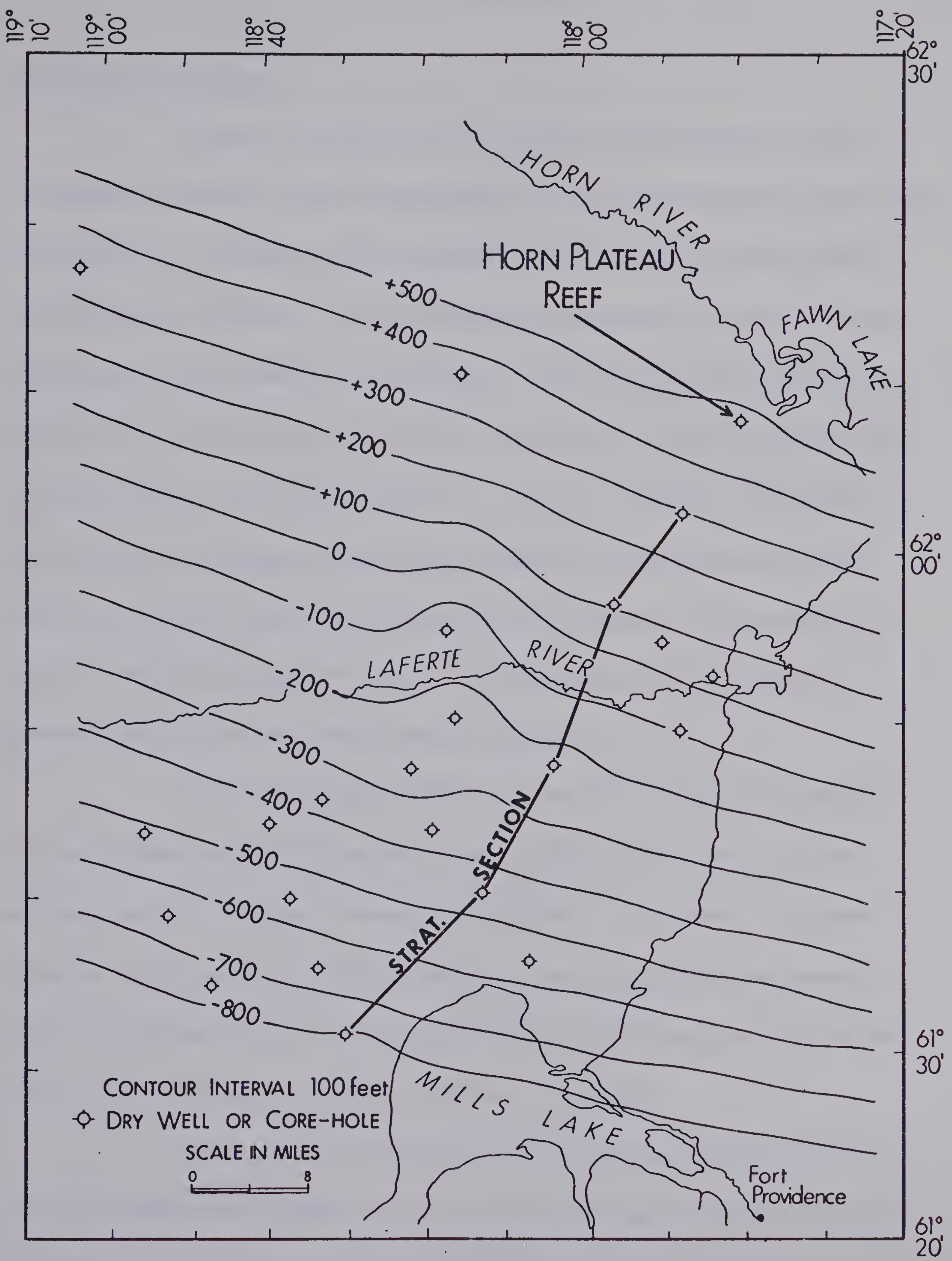


Fig. 6. Structure contour map of the Lonely Bay Formation.

HORN PLATEAU REEF

Geometry and Structure

In plan, the reef outcrop is circular, approximately 0.4 miles in diameter, and has a relief of approximately 50 to 60 feet above the surrounding terrain (Fig. 2). The strata of the periphery of the outcrop are inclined away from the center of the reef. In the northeasterly quadrant of the reefal outcrop the carbonate rock is massive and unbedded. On the reef top the sediments are mainly sand sized and are typically flaggy weathered. Much of the strata of the outcrop periphery are inclined away from the center of the reef. The dips of these strata are interpreted to be primary depositional features and not due to tectonic movement, however no geopetal fabrics were seen. The steepest dip is in the northeasterly quadrant where it is 35 degrees. In the southwestern quadrant the dips are more gentle, about 15 degrees.

To date (September, 1969), the maximum measured thickness of the Horn Plateau reef is 402 feet but further drilling might reveal additional section. The reef is known to extend for 3720 feet in a northwest - southeast direction. The core-hole control is sparse but from the projected sedimentary dips it is quite possible that in the subsurface the Horn Plateau reef is approximately circular in shape and attains a diameter of 0.8 miles.

The black shale of the Horn River Formation in Core-hole Nos. 2, 3, and 5 drapes over the reefal structure with a dip of approximately 15 degrees. The shale in Core-hole No. 4, with the exception of 10 feet immediately overlying the Horn Plateau reef, is essentially flat lying. This 10 foot shale unit has a dip of 2 to 3 degrees which implies that the underlying carbonate buildup is not very great.

Macrofacies of the Reef

By utilizing faunal and sedimentary evidence, the Horn Plateau reef has been divided into 3 macrofacies: organic reef, reef flat, and reef flank (Figs. 7 & 8). It will be shown in the section dealing with paleoecology that there was a dominant northeasterly wind, and when the postulated wind direction is taken into account, a subdivision of the reef flank into windward reef flank and leeward reef flank results.

The organic reef facies in outcrop is confined mainly to the northeastern quadrant, where stack and pillar erosion occurs (see Frontispiece), but chain-like organic reef features are found on the hillside in the southern area. The facies is characterized by a massive framework of in situ colonial corals and massive and tabular stromatoporoids surrounded by sand and gravel sized crinoid and coral sediments (Pl. I, Figs. 1,4,5, and 6). Core-hole No. 1 is almost entirely composed of a well developed organic reef facies, whereas Core-hole Nos. 2 and 3 have a "starved-type" organic reef facies.

In outcrop, the reef flat facies, which is found on the reef top, consists of low rubbly outcrops (Pl. I, Fig. 7) usually 10 to 20 feet in diameter. In the subsurface it is found associated with the reef flank and organic reef facies in Core-hole Nos. 2,3, and 5, and with the organic reef facies in Core-hole No. 1. This facies is composed mostly of sand sized skeletal sediments cemented by sparry calcite cement. Scattered brachiopods, corals, trilobites, and stromatoporoids are commonly present.

The reef flank facies occurs on the outcrop periphery and consists of inclined strata which dip away from the organic reef and reef flat facies. As much as 20 feet of strata inclined at approximately 35 degrees can be measured in the northeastern quadrant of the reef. The reefal material in Core-hole No. 5 is represented entirely by the reef flank facies. It also occurs in Core-hole

Fig. 7. Facies distribution on the Horn Plateau reef surface.

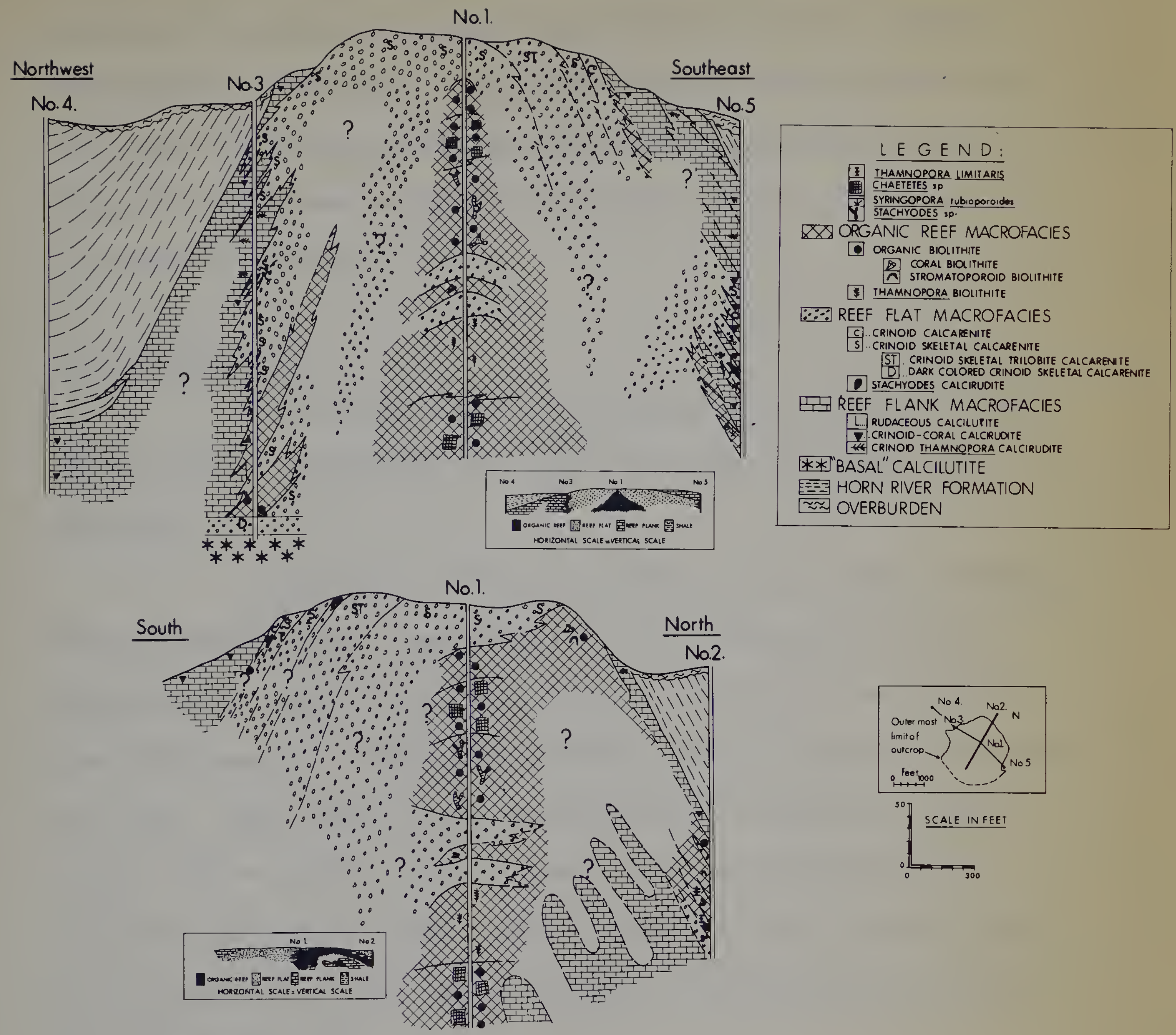


Fig. 8. Structural cross sections of the Horn Plateau reef illustrating interpreted facies distribution.

Nos. 2,3, and 4. This facies is composed mainly of gravel sized crinoid and coral sediments cemented by sparry calcite cement.

In outcrop, the reef flank facies grades laterally in a south-easterly direction away from the reef from a calcirudite through a rudaceous calcilutite into a calcilutite. It is possible that this calcilutite could be "off reef" material but outcrop is insufficient to make this interpretation certain. No prominent difference was observed between the sediments of the windward and leeward reef flanks.

Textural Components

Five textural components characterize the limestones of the Horn Plateau reef: (l) framebuilders, (2) grains, (3) micrite, (4) cement, and (5) pores.

Frame builders - These are organisms that are capable of building wave-resistant structures. Framebuilders of the Horn Plateau reef in order of importance are: colonial and branching-type corals and massive and tabular-type stromatoporoids. These form the biolithites which are common in the organic reef facies. Algal material, as in some other Devonian reefs (Klovan, l964; Leavitt; l968, and others) is not widespread. Its apparent insignificance is problematic because, as in modern reefs, it most likely was an important agent in the formation of the reef. Further discussion of the framebuilders is found in the paleoecology section.

Grains (discrete particles larger than 0.063 mm.) - Grains in the limestones of the Horn Plateau reef consist of fragmental and nonfragmental skeletal particles. Generally the reefal limestones are composed of varying amounts and sizes of 5 skeletal grain types. In order of importance these are: crinoid, tabulate and rugose solitary coral, brachiopod, and stromatoporoid debris. Crinoid particles in the reef flat facies commonly comprise between

70 and 80 percent of the rock by volume. Minor occurring types of skeletal grains include trilobites, gastropods, and bryozoan fragments, as well as tentaculitids, ostracods, and conodonts. These occur scattered throughout the reef and generally no one of these minor component grains comprises more than 10 percent of the rock.

Micrite (material less than 0.063 mm) and Calcite Spar Cement - With the exception of the size limit for micrite, these terms follow the definitions of Leighton and Pendexter (1962, pp. 59 - 60). Micrite is more common in the reef flank than in either the organic reef or reef flat facies. Its content in the reefal limestones is low and generally does not exceed 10 percent of the rock by volume, although in the outermost outcrop periphery up to 80 percent is present. The calcite spar is found throughout the reef, occurring as pore-filling cement and as a recrystallization product.

Pores - Harbaugh (1967) gives a summary of recent work done on porosity in carbonate oil reservoir rocks. His arbitrary division of carbonate porosity, that is, primary and secondary types, is followed in this project. Types of primary porosity include: (1) framework, here referred to as intraskeletal and intragranular porosity, (2) sand, here referred to as interskeletal porosity. Generally, intraskeletal porosity is more important than interskeletal porosity in the Horn Plateau reef. The terms trace, poor, fair, and good porosity are rough visual estimates which would correspond to approximately less than 1, 1 to 3, 3 to 10, and greater than 10 percent, respectively.

Good porosity is best developed in the reef flank facies. Many of the rocks in the organic reef facies are highly cemented with sparry calcite which has obliterated much of the original porosity; overall, only fair porosity is now present in this facies. In the reef flat, fair to good interskeletal porosity remains between crinoid particles. Whenever stromatoporoid debris occurs

there is usually some intraskeletal porosity.

Minor Textural Modifiers - Additional materials such as hydrocarbons, (Pl. 7, Fig. 14) pyrite, dolomite, pellets (Pl. 7, Fig. 11), argillaceous material, and authigenic quartz are of minor quantitative importance in the Horn Plateau reef.

Diagenesis

The Horn Plateau Formation has been subjected to relatively minor depositional alteration. Calcite cementation and subsequent neomorphism (Folk, 1965) are the most important effects of diagenesis. There are minor occurrences of: 1) selective dolomitization of skeletal material - stromatoporoids were especially prone to this type of replacement; 2) development of authigenic quartz grains 1 - 2 mm in diameter within Alveolites; 3) stylolite development as a result of compaction; 4) fracturing and subsequent mechanical infilling. In the early stages of diagenesis algal activity resulted in micrite envelopes. A complete treatment of these diagenetic effects was not attempted; instead, a thorough study should be devoted to it.

Paleontology

Table 3 is a complete list of the identified fauna of the Horn Plateau reef. Where possible, their location and relative abundance within the macrofacies and microfacies are shown. Of the fauna identified by the present writer, 8 brachiopods, 12 corals, 1 echinoderm, 4 gastropods, 1 pelecypod, and the total algae and stromatoporoid suites had not been previously reported [by McLaren and Norris (1964) and others] from the Horn Plateau Formation. More detailed work on the fauna may bring about certain revisions in the identifications. This is especially true of the stromatoporoid fauna.

The general distribution of the fauna across the reef is shown

Table 3: Complete List of identified taxa of the Horn Plateau Formation

		MACROFACIES				MICROFACIES												
						Reef Flat			Organic Reef				Reef Flank					
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)
	Footnotes	Leeward Reef Flank	Reef Flat	Organic Reef	Windward Reef Flank	Crinoid Calcarenite	Crinoid Skeletal Calcarenite	Stachyodes Calcirudite	Organic Biolithite	Var. Coral	Var. Stromatoporoid	Thamnopora Biolithite	Crinoid-Coral Calcirudite	Crinoid Thamnopora Calcirudite	Rudaceous Calcilutite	Calcilutite	Brachiopod Calcirudite	"Basal" Calcilutite
ALGAE	1	R	R	R	R	X	X		X			X						
Sphaerocodium ? sp.	1	R											X					
BRACHIOPODA	2	C	A	A	A	X	X	X	X	X	X		X	X	X	X	X	X
Ambocoelia cf. A. umbonata (Conrad)	3				A													
A. sp.	1	R											X					
Ambothyris ? sp.	1	R											X					

Table 3 ....Continued

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)
Athyris aquilonius Norris	2	A											X					
Atrypa nasuta Norris	2		A	C	C	X	X		X				X				X	
A. nasuta hearnei Norris	2		R	R		X	X											
Camarotoechia sp.	1		A			X												
Cranaena ? sp.	2	A	R			X							X			X	X	
C? cryptonelloides Norris	2	A	A	C		X			X				X					
Cymostrophia sp.	3				R													
Eleutherokomma implanta Norris	3				C													
Emanuella ? sp.	2		R	C		X			X									
E. cf. E. meristoides (Meek)	3				R											X		
Gypidula ? sp.	2				R													
G. cf. G. comis (Owen)	1		R		C		X									X		
Hypothyridina cameroni Warren					R													
Leiorhynchus cf. L. awokanak McLaren	1				R								X					
L? matonabbee Norris	3				R													
Leptagonia ? rhomboidalis (Wilckens)	2		R		R		X						X					

Table 3 ....Continued

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)
Longispina whittakeri Norris	3			R	R													
Pentamerella sp.	3	R			R													
P. sclavus Norris	2		R		R		X											
Pholidostrophia ? sp.	3				R													
Schizophoria manitobensis Whiteaves	1		C	R	A		X		X				X					
Schuchertella sp.	1		R				X											
Sieberella? newtonensis Imbrie	2				R								X					
Spinatrypa hornensis Norris	2		R	R	A		X						X					
Spinulicosta sp.	3				R													
Stropheodonta sp.	1	R			R								X					
Trematospira sp.	3				R													
BRYOZOA	1				R										X	X	X	
COELENTERATA	2	A	C	A	A	X	X	X	X	X		X	X	X	X	X	X	X
Alveolites sp.	1			A					X	X								
Atelophyllum nebracis McLaren	2	C	R	C	C	X			X				X					
Australophyllum ? cf. A ? thomasae (Hill and Jones)	2			A					X	X								

Table 3 ....Continued

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)
Buschophyllum ? sp.	1		R				X											
Chaetetes sp.	1			A					X									
Cyathophyllum greteneri McLaren	3																	
C. greteneri n. var. A	1	C	R	A	R		X			X			X					
Cylindrophyllum gruensis McLaren	3																	
Cystiphylloides spinosum McLaren	2	C	C	C	C	X	X		X				X					
Disphyllum goldfussi (Geinitz)	1		R	R			X		X									
D. salicis McLaren	2	R		R					X				X					
Favosites sp.	3																	
F. alpenensis Winchell	1			R	R				X				X					
F. inosculis	1	R	R	C			X		X	X								
Grypophyllum cornus McLaren	3																	
Heliophyllum borealis McLaren	2		R		C	X							X					
Hexagonaria n. sp?	1			R					X									
Lexanophyllum cf. L. punctatum Wedekind	3																	
Neostringophyllum craigi McLaren	2	R		R	R				X				X	X				

Table 3 ....Continued

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)
Sinospongophyllum cf. S. planotabulatum Yoh	2		R	A	R		X		X	X			X					
Siphonophrentis ? sp.	3																	
Stringophyllum redactum McLaren	2			A					X	X								
Syringopora cf. S. rockfordensis (Fenton and Fenton)	1		R	R	R		X		X						X			
S. cf. S. tubiporoides Billings	1			C						X								
Thamnopora limitaris (Rominger)	1	C	C	A	C	X	X	X	X	X		X	X	X	X	X		X
Utaratuia cf. U. laevigata Crickmay	1			A					X	X								
CONODONTOPHORIDA	1	R	R	R	R		X		X			X	X					
ECHINODERMATA	2	A	A	A	A	X	X	X	X	X	X	X	X	X	X	X	X	X
Gasterocoma ? sp.	1																	
GASTROPODA	1	R	R	R	R	X	X		X				X				X	X
Ceratopea ? sp.	1	R											X					
Mastigospira ? sp.	1		R				X											
Platyceras sp.	1		R				X											
Straparollus sp.	1		R				X											

Table 3 ....Continued

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)
OSTRACODA	1	R	R	R	R	X			X				X	X				
Rozhdestuenskayites sp.	1				R								X					
PELECYPODA	2	R			R													
Conocardium sp.	2				R								X					
Leptodesma sp.	1				R								X					
STROMATOPOROIDS	1					X	X	X	X		X		X	X	X		X	
Actinostroma sp.	1			R					X									
Atelodictyon sp.	1		R	R			X		X									
Clathrocoilona sp.	1			R					X									
Clathrodictyon sp.	1		R				X											
Euryamphipora ? sp.	1		R				X											
Hermatostroma sp.	1				R								X					
Parallelopora sp.	1			R					X									
Stachyodes sp.	1		C	C	C			X					X					
Stromatopora sp.	1	R	C	A	A		X		X		X				X			
Trupetostroma sp.	1		C	R	C		X		X				X					

Table 3 ....Continued

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)
T. cf. T. kakisaense Stearn	1				R				X									
TENTACULITID	1	R	C	R	R	X	X		X				X	X	X	X		
Tentaculities sp.	1	R	C	R	R	X	X		X				X	X	X	X		

Footnotes:

Taxa from the Horn Plateau Formation which:

1) have not been reported previously.

2) were found in this study and have also been reported previously.

3) were reported by McLaren & Norris (1964) but were not found by the present writer. (It is interpreted that Norris's lower thin-bedded and upper thick-bedded units are the reef flank and organic reef macrofacies, respectively, of this study.)

R = Rare; C = Common; A = Abundant

in Fig. 9. The organic reef microfacies is characterized by the presence of abundant colonial corals and massive and tabular stromatoparoids. The latter occur to a lesser extent in the reef flat and the reef flank facies. The trilobites are restricted to the reef flat, and both the bryozoans and pelecypods to the reef flank. The remaining fauna occur to varying degrees in all of the facies.

The geographic distribution and relative abundance of the fauna on the exhumed reef surface (present outcrop) is shown in Figs. 12 and 13. The percentages are visual estimaes of the fauna in the collected hand samples. Repeated point count annalyses of hand samples indicates that the error is less than 15 percent of the amount estimated. The significance of location and abundance of the fauna will be dealt with in detail in the paleoecology section.

Petrographic Classification

Numerous carbonate classifications have been presented in recent geological publications (for a review see Bissell and Chilingar, 1967) but none were completely satisfactory for the Horn Plateau reef limestones. Various workers (Jenik and Lerbekmo, 1968; Leavitt, 1968, and others) have found it desirable to modify published classifications for particular suites of reef carbonates; the same approach has been followed in this study.

The size, type and relative abundance of the skeletal grains and framebuilders are the basic criteria used in classifying the Horn Plateau reef limestone. The rock nomenclature is a modification of that of Grabau (1904, 1913). The grain-size scale follows that of Wentworth (1922). Calcirudite, calcarenite, and calcilutite are composed predominantly of gravel, sand, and mud size particles respectively. These terms have no genetic inference. Biolithite is applied to rocks comprised of <u>in situ</u> framebuilding structures (Folk, (1962).

The rock nomenclature is preceeded by the major fauna present,

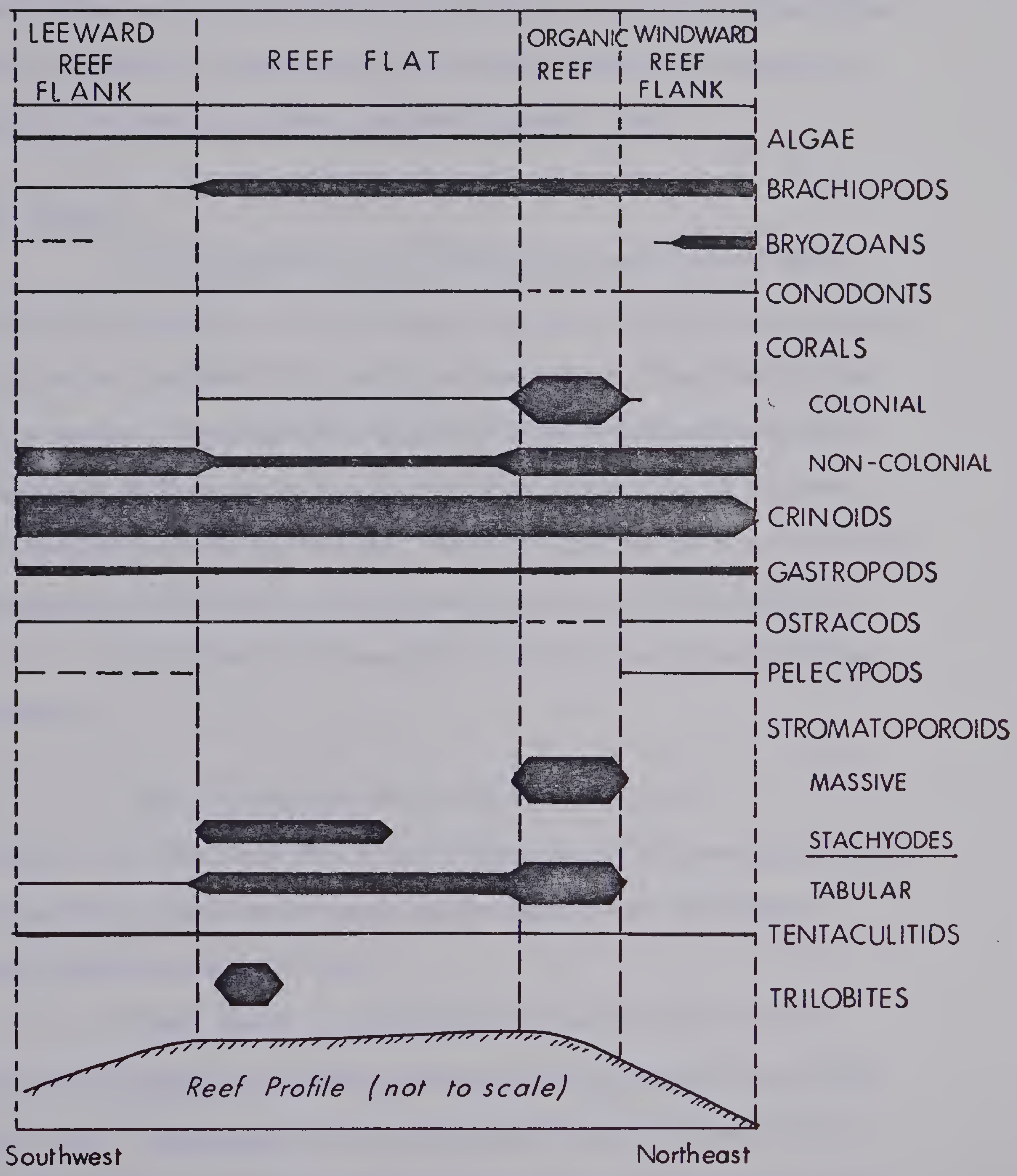


Fig. 9. Diagrammatic distribution of the fauna and flora on the Horn Plateau reef surface. Thickness of bar indicates relative abundance of organism.

which are named in order of importance, e.g., crinoid trilobite calcarenite. A hyphen between organisms indicates that they vary in volumetric importance. Other modifiers are used where deemed appropriate, e.g., dark-colored crinoid skeletal calcarenite. Where practicable the color of these rocks follows that proposed by the rock-color chart committee (Goddard, 1951).

Facies Analysis

The 3 macrofacies can be subdivided according to the above criteria into 11 microfacies. Two of these, (rudaceous calcilutite and calcilutite microfacies) are restricted to the outcrop surface and one ("basal" calcilutite) to the subsurface. The geographic distribution of the established microfacies on the outcrop is illustrated in Fig. 7. Two cross sections (Fig. 8) illustrate the facies distribution through the reef. Control is good for the outcrop material, but is sparse for the subsurface; the cross sections are thus fairly interpretive.

The following is a description and discussion of the established microfacies.

"Basal" Calcilutite Microfacies (Pl. 8, Fig. 1)

Description: Brownish black (5YR 2/1); >95%* micrite ; <5% skeletal grains (<2% particles >2mm.); trace amounts sparry calcite cement; well sorted; tight; numerous stylolites and pyrite "blebs".

Fossils consist of: crinoids (ranging from 0.7 to 6.3 mm. in diameter); Thamnopora; unidentifable brachiopods and gastropods; a two-holed crinoid ossicle - Gastercoma? (Pl. 5, Fig. 21) at 357 feet in Core-hole No. 3.

Discussion: This rock type is restricted to the subsurface, occurring from 346.5 to 358 feet in the lowest part of Core-hole No. 3. The contact of this rock type with the overlying dark-brownish-grey crinoid skeletal calcarenite is gradational.

* % refers to bulk volume of rock unless otherwise stated.

J.K. Evans (pers. comm., 1969) states that the basal calcilutite microfacies is similar to the lithology of the uppermost portion of the Lonely Bay Formation. This suggests that the reef is "rooted in" or on this formation and that the reef foundation was an unconsolidated mud and not a hard substrate. Similar "basal units have been reported from the Swan Hills reefs" (Murray, 1966, pp. 32 - 34, and Jenik and Lerbekmo, 1968, p. 41), and a similar environment of deposition is interpreted; that is, a quiet marine environment with perhaps some restricted circulation.

Organic Reef Macrofacies:

This macrofacies consists of: 1) Thamnopora biolithite and 2) organic biolithite microfacies. Where practicable the latter is named after the most prominent genus or genera in the assemblage, e.g., the Chaetetes stromatoporoid biolithite. A few situations were observed where either corals or stromatoporoids appear separately. These are referred to as coral biolithite and stromatoporoid biolithite, respectively, two varieties of the organic biolithite; however, the total "absence" of one group or the other cannot be established with certainty owing to the small core diameter.

Thamnopora Biolithite Microfacies (Pl. 8, Fig. 2)

Description: Light to dark olive grey; coarse sand to pebble size; 60 - 90% skeletal grains; largely Thamnopora limitaris >2 mm ; 10 - 40% micrite; trace amounts calcite cement; well sorted; tight.

Fossils consist of: Thamnopora limitaris, >60%, up to 6 cm long and 2.5 cm in diameter; crinoids, <10%; and algal material.

Discussion: This biolithite is restricted to the subsurface, occurring from 223 - 285 feet in Core-hole No. 1. Stromatoporoids and other corals are "absent".

Organic Biolithite Microfacies:

Description: Massive weathering; light grey to brownish grey, medium sand to pebble size; >60% skeletal grains >2 mm (high percentage of in situ colonial corals and stromatoporoids), 10 - 30% sparry calcite cement; trace amounts micrite and dolomite; poorly sorted; porosity variable from tight to good.

Fossils consist of: corals - Alveolites, Atelophyllum, Australophyllum, Chaetetes, Cystiphylloides, Disphyllum, Favosites, Hexagonaria, Neostringophyllum, Sinospongophyllum, Stringophyllum, Syringopora, Thamnopora, and Utaratuia; stromatoporoids - Actinostroma, Atelodictyon, Clathrocoilona, Parallelopora, Stromatopora, Trupetostroma, and T. cf. T. kakisaense; brachiopods (see Table 3); crinoid debris; ostracods; conodonts; gastropods; tentaculitids - Tentaculites; trace amounts algae.

Discussion: In outcrop, this rock type is found throughout the organic reef facies. It occurs in Core-hole Nos. 1,2, and 3, and is commonly characterized by certain genera.

The massive coral Chaetetes is prominent in the lower 51 foot unit of Core-hole No. 1 (Fig. 8); other corals present consist of Alveolites and Syringopora; the stromatoporoids are represented by Clathrocoilona and Stromatopora. This unit is designated the Chaetetes - stromatoporoid biolithite. From 102 - 172 feet in the same core-hole, corals and stromatoporoids form a coral - Stachyodes biolithite. None of the corals present - Atelophyllum, Chaetetes, and Stringophyllum are dominant. Stachyodes is more abundant than Stromatopora, the other stromatoporoid present. Overlying this unit from 62 - 102 feet a Chaetetes - stromatoporoid biolithite occurs. Stromatoporoids present are Atelodictyon, Palallelopora, and Stromatopora. This unit is similar to the lower 51-foot unit described above. An organic biolithite overlies this unit from 34 - 62 feet. Corals present consist of Australophyllum, Favosites, and

Syringopora redactum. Stromatoporouds are represented by Actinostroma and Stromatopora. The 4 foot breccia referred to earlier is present within this last unit.

In Core-hole No. 2 the organic biolithite is present from 139 - 154 feet and from 209 - 220 feet. This latter unit is referred to as a Thamnopora stromatoporoid biolithite; Thamnopora and Stromatopora are both abundant. In the upper unit no genus is dominant. Corals and tabular stromatoporoids present consist of Hexagonaria, Neostingophyllum, Thamnopora, Stromatopora, Trupetostroma, and T. cf. T. kakisaense. In Core-hole No. 3 the organic biolithite is present from 306 - 331.5 feet. Corals present consist of Atelophyllum, Chaetetes, and Disphyllum, and there are branching Stachyodes and unidentifiable tabular stromatoporoids.

Coral Biolithite Microfacies (Variety)

Description: Same as organic biolithite except stromatoporoids are "absent".

Fossils consist of: corals - Alveolites, Australophyllum, Cyathophyllum, Favosites, Sinosponogophyllum, Stringophyllum, Syringopora, Thamnopora, and Utaratuia?; crinoids; and unidentifiable brachiopods.

Discussion: The distribution of this microfacies variety is not widespread, occurring as thin units in Core-hole Nos. 1, 2, 3, and 5. There is more gravel and less sand sized material in Core-hole Nos. 2, 3, and 5 than in No. 1. The latter has a more lush growth of framebuilders than the other core-holes.

In outcrop, the area covered by coral biolithite is not outlined, but probably locality 99 (Pl. 1, Fig. 5) could be referred to as a coral biolithite. Here Utaratuia? forms a coral bed 6 feet thick. The presence of stromatoporoids at this locality is uncertain.

Stromatoporoid Biolithite Microfacies (Variety)

Description: Same as organic biolithite except that corals are "absent".

Fossils consist of: Stromatopora and other stromatoporoids, > 60%; crinoids, < 30%; brachiopods, in trace amounts.

Discussion: This rock type does not seem to have other framebuilders present. It is found only in Core-hole Nos. 2, and 5, and is not important volumetrically.

Reef Flat Macrofacies

This macrofacies is characterized by 3 microfacies: crinoid calcarenite, crinoid skeletal calcarenite, and Stachyodes calcirudite. By volume, the first 2 are most prevalent and each has a "trilobite" variety - crinoid trilobite calcarenite and crinoid skeletal trilobite calcarenite, respectively.

Crinoid Calcarenite Microfacies (Pl. 8 Figs. 7 & 8)

Description: Flaggy weathering; olive grey to brownish grey; coarse to very coarse grained; 70 - 90% skeletal grains (particles >2 mm in only trace amounts); 10 - 20% sparry calcite cement; trace amounts micrite: well sorted; good intraskeletal and interskeletal porosity.

Fossils consist of; crinoids, 70 - 90% (generally 0.5 - 2 mm in diameter, occasionally 3 - 4 mm, and rarely up to 11 mm); brachiopods - Atrypa nasuta, A. nasuta hearnei, Cranaene? cryptonelloides, Emanuella; corals, < 5% - Atelophyllum nebracis, Cystiphylloides spinosum, Heliophyllum borealis, and Thamnopora; stromatoporoid debris, < 10%; unidentifiable gastropods; ostracods; and Tentaculites.

Discussion: In the subsurface, this rock type, which could be referred to as an encrinite, occurs to a minor extent in Core-hole Nos. 3, and 5. As on the surface, it is found in close association with the crinoid skeletal calcarenite.

In outcrop, trilobites - Dechenella occur within the crinoid calcarenite microfacies (Fig. 8), and in a random hand sample 3 - 10 can be observed. A variety of the crinoid calcarenite, the crinoid trilobite calcarenite, was established

to outline this area. This variety is restricted to the southwestern quadrant of the reef outcrop (Fig. 7).

Crinoid Skeletal Calcarenite Microfacies (Pl. 8, Fig. 9)

Description: Light grey to dark brownish grey; fine sand to cobble size, but generally coarse to very coarse grained sand; 60 - 90% skeletal grains (particles >2 mm up to 30% but usually <10%); sparry calcite cement, trace amounts micrite; fair to well sorted; fair to good interskeletal and intraskeletal porosity.

Fossils consist of: crinoids, 50 - 90% (generally 0.5 - 2 mm in diameter, but an occasional ossicle up to 8 mm); brachiopods, generally <10% - Atrypa nasuta, A. nasuta hearnei, Camarotoechia, Cranaena, Gypidula, Leptagonia, Pentamerella, Schizophoria, Schuchertella, Spinatrypa; corals, <10% - Alveolites debris, Cyathophyllum, Cystiphylloides, Disphyllum, Favosites inosculis, Sinospongophyllum, Syringopora, and Thamnopora; gastropods, <1% - Mastigospira?, Platyceras, Straparollus; tabular stromatoporoids, <10% - Atelodictyon, Clathrodictyon, Stromatopora, Trupetostroma; Stachyodes debris; Tentaculites; trace amounts algae; and conodonts.

Discussion: The crinoid skeletal calcarenite is usually light grey, but a dark brownish grey variety exists (Pl. 8, Fig. 10). The former is found in both the surface and subsurface; the latter occurs only in Core-hole No. 3 from 331.5 - 346.5 feet. The dark colored unit gradationally overlies the "basal" calcilutite and is gradationally overlain by an organic biolithite. A 2 - foot unit with abundant Thamnopora occurs near the bottom of this calcarenite. Thicker basal, branching coral - stromatoporoid units have been reported in the Swan Hills reefs (Fong, 1959, 1960; Fischbuch, 1968; and others). The possibility exists that in many of the Devonian reefs some form of branching coral acted as the pioneer population and gained a foothold on the unconsolidated muddy or sandy reef foundation prior to reef growth.

In the crinoid skeletal calcarenite, as in the crinoid calcarenite,

trilobites occur within the microfacies. As before, a variety of the crinoid skeletal calcarenite was established, that is, crinoid skeletal trilobite calcarenite (Fig. 7).

Stachyodes Calcirudite Microfacies (Pl. 8, Fig. 5)

Description: Weathers to yellowish grey (5Y8/1); light olive grey (5Y6/1); coarse sand to pebble size, but generally granule to pebble; in outcrop, 50 - 70% skeletal grains (50 - 60%>2 mm, mostly Stachyodes), 30 - 50% micrite, trace amounts void - filling sparry calcite cement; in subsurface, 70 - 90% skeletal grains, 10 - 30% sparry calcite cement; well sorted; tight.

Fossils other than Stachyodes consist of unidentifiable brachiopods, crinoid debris, and Thamnopora.

Discussion: This microfacies is restricted to 3 outcrops (Fig. 7) and is encircled by the crinoid skeletal calcarenite and its variety, the crinoid skeletal trilobite calcarenite. In subsurface it occurs from 198 - 208 feet in Core-hole No. 5. The stromatoporoids are probably in or near original growth position.

Reef Flank Macrofacies

This facies is characterized by 4 microfacies: crinoid - coral calcirudite, crinoid Thamnopora calcirudite, rudaceous calcilutite, and calcilutite. All 4 occur on the outermost periphery of the reef and the first 2 are dominant.

Crinoid - Coral Calcirudite Microfacies (Pl. 8, Fig. 3)

Description: Dark yellowish grey to dark olive grey; medium sand to pebble size; 60 - 90% skeletal grains (20 - 60%>2 mm, mostly crinoids and solitary corals); 10 - 30% sparry calcite cement and micrite; trace amounts dolomite; poor to fair sorting; poor to good (commonly good) interskeletal and intraskeletal porosity.

Fossils consist of: crinoids (up to 2.5 cm); corals - Atelophyllum, Cyathophyllum,

Cystiphylloides, Disphyllum salicis, Favosites, Heliophyllum, Neostringophyllum craigi, Sinospongophyllum, and Thamnopora; brachiopods - Ambocoelia, Ambothyris, Athyris, Atrypa, Cranaena, Leiorhynchus, Leptagonia, Schizophoria, Sieberella, Spinatrypa, Stropheodonta; Stachyodes; tabular stromatoporoids - Hermatostroma, Trupetostroma; stromatoporoid debris; gastropods - Ceratopea?; Tentaculites; ostracods; pelecypods; and conodonts.

Discussion: This rock type is the most widespread and abundant microfacies of the reef flank macrofacies. The reef material in Core-hole No. 4 is represented entirely by the crinoid - coral calcirudite. This calcirudite also occurs in Core-hole Nos. 2, 3, and 5, and around the entire periphery of the reefal outcrop.

Crinoid Thamnopora Calcirudite Microfacies (Pl. 8, Fig. 4)

Description: Grey to brownish grey; fine sand to pebble size; 60 - 80% skeletal grains (20 - 70%>2 mm, largely crinoids and Thamnopora rubble); 10 - 30% sparry calcite cement; poor to fair sorted; tight to good (commonly fair) interskeletal and intraskeletal porosity.

Fossils present consist of: crinoids (up to 1.5 cm in diameter); corals - Thamnopora (abundant), Neostringophyllum; brachiopods; stromatoporoid debris - Stachyodes; ostracods; and Tentaculites.

Discussion: This rock type is found occasionally at the surface and in Core-hole Nos. 3 and 5.

Rudaceous Calcilutite Microfacies (Pl. 8, Fig. 6)

Description: Dark yellowish brown (10YR 4/2); 40 - 70% micrite; 20 - 50% skeletal grains (10 - 30%>2 mm; < 10% sparry calcite cement; fair to well sorted; tight.

Fossils consist of: corals - Syringopora rockfordensis, Thamnopora; crinoids (up to 4.6 mm); stromatoporoids - Stromatopora; brachiopods; bryozoans;

and Tentaculites.

Discussion: This rock type occurs at 3 localities (16A, 58, and 76B), all on the outermost periphery of the outcrop. It probably represents the transition between the calcilutite and calcirudite microfacies.

Calcilutite

Description: Dark yellowish brown (10YR 4/2); ≥80% micrite; <20% skeletal grains (>2 mm in trace amounts only), trace amounts sparry calcite cement; well sorted; fair intraskeletal and pinpoint porosity.

Fossils present consist of: tabulate corals - Thamnopora; brachiopods - Emanuella, Cranaena?, Gypidula; crinoids; Tentaculites; and bryozoans

Discussion: This rock type is represented at only one locality, (16B) in the south-east quadrant of the reefal outcrop.

Brachiopod Calcirudite Microfacies (Pl. 7, Figs. 12 & 13)

Description: A "type" description of this rock type is difficult since both the brachiopods and matrix vary greatly in quantity geographically. Light grey to dark brown; micritic to pebble grained (commonly pebble grained); 20 - 70% skeletal grains (20 - 60% 2 mm, >20% brachiopods; up to 80% micrite; up to 30% sparry calcite cement; trace dolomite; poor to well sorted; trace to fair porosity.

Fossils consist of: brachiopods - Atrypa nasuta, Cranaena?; crinoids; corals; stromatoporoid debris; bryozoans; and gastropods.

Discussion: This rock type occurs in all the reef macrofacies, is restricted to the surface material, but does not contribute significantly to the bulk volume of the reef. Except for the brachiopods at locality 23, they are entirely unfragmented.

The preceding concludes the detailed facies analysis. Figure 10 diagrammatically illustrates the main textural features of the microfacies; the varieties are not illustrated.

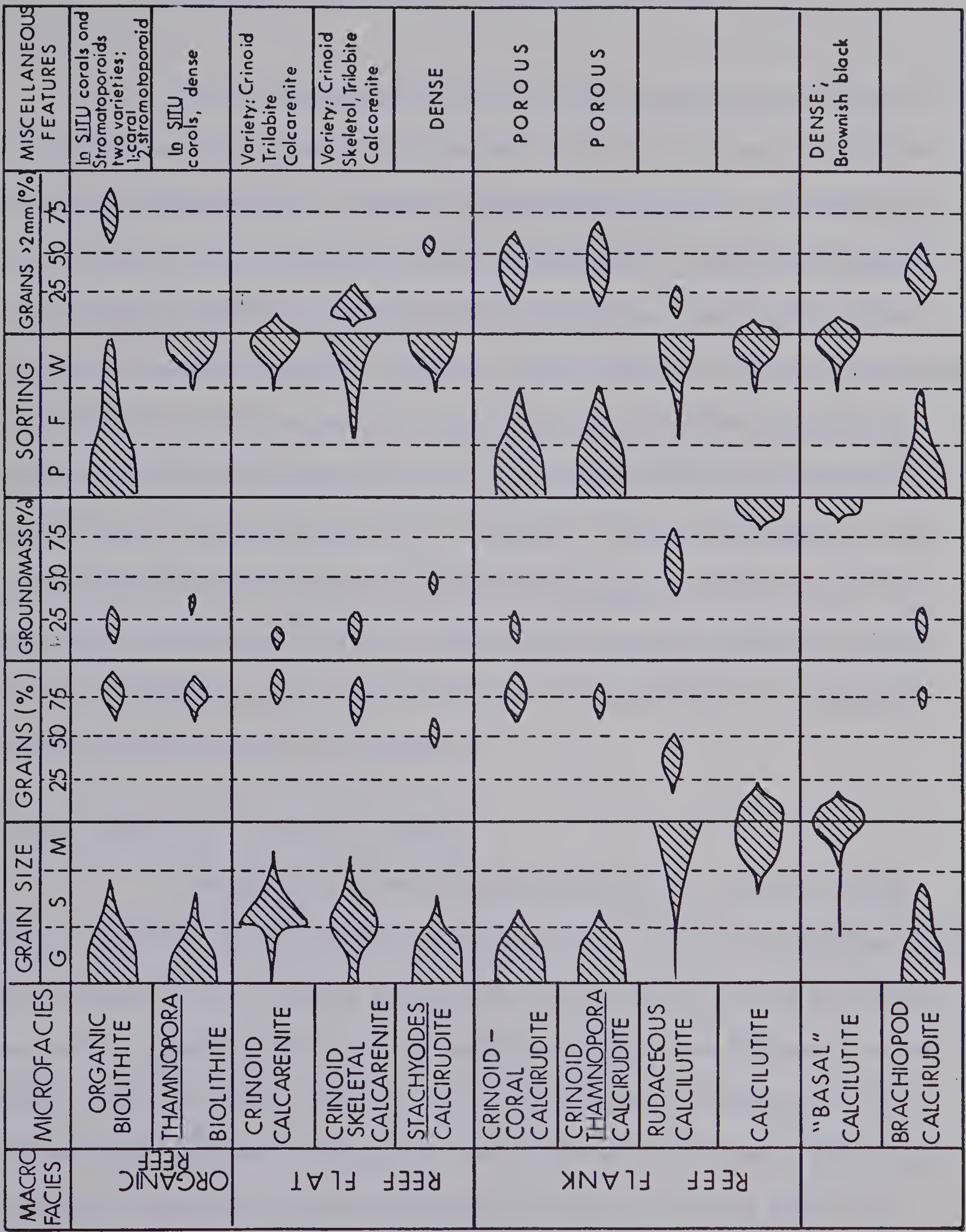


Fig. 10. Main textural features of the microfacies of the Horn Plateau reef. Width of hachured area indicates relative abundance. G=Gravel, S=Sand, M=Mud, P=Poor, F=Fair, W=Well.

PALEOECOLOGY AND PALEOENVIRONMENT

The environments of the fauna and the depositional conditions of the sediments will be discussed in this section. The writer's approach is to follow the belief of Hecker (1965, p. 15) that in paleoecology the place of habitat of an organism and its place of burial should be differentiated. Since Hutton proposed the Principle of Uniformity, geologists have been studying recent models so that they may extrapolate to ancient conditions. These models and information from other paleoecological studies are used to interpret the living conditions and place of habitat of the Horn Plateau reef organisms. The fossil distributions illustrate the place of burial, but not necessarily the living sites. Determining whether or not a fossil organism has been found at its death site (*in situ*) is usually easier for the sessile than for the vagrant benthos. Factors such as amount of abrasion, position of valves, articulation, etc., must all be taken into consideration in attempting to establish the living place of an organism.

Winds, Currents, and Geological Setting

Although types of reef building organisms have changed through time, it is unlikely that physical forces affecting reefs, namely, winds and currents have changed much. According to Potter and Pettijohn (1963, p. 185) reef shapes are usually a result of currents, as they supply nourishment that influences growth patterns, but, as Fairbridge (1950, pp. 356 - 357) observed, currents and winds do not necessarily coincide, but they do control development and form of coral reefs. If reefs with sedimentary and gross morphologic features resembling those of the Horn Plateau reef are presently forming, then a similar geographic situation and paleoenvironment during the Horn Plateau reefal growth can perhaps logically be inferred. Caution, however, must be used in interpreting ancient environments from the shapes of modern reefs alone since, as Fairbridge (ibid., p. 358) and

Maxwell (1968, p. 101) have illustrated, reefs pass through various stages of evolution.

Small patch reefs are presently forming at various places on the Australian continental shelves (Fairbridge, 1950, pp. 345 - 349). Two regions off Western Australia are: 1) Abrolhas reefs near Geraldton and 2) reefs on the northern part of the Sahul Shelf near Derby. Other occurrences are in Clarence Straits, Northern Territories and Torres Straits, the channel between Australia and New Guinea. Alternating wind and current directions in both these straits results in long narrow reefs, and reefs of the Abrolhos region (Fairbridge, 1948) have a complex morphology. In contrast to these reefs, the Horn Plateau reef is nearly circular in shape. Perhaps the best modern analogies to the Horn Plateau reef are the Sahul Shelf reefs. These small patch reefs rise out of a depth of between 20 and 100 fathoms (Teichert and Fairbridge, 1948), and their gross features closely resemble the macrofacies of the Horn Plateau Formation. Generally, they have a central sand flat, are surrounded by coral shingle debris, and have a dominant in situ coral growth on the predominantly windward side. Teichert and Fairbridge observed that for 8 months of the year there are southeast winds and for the other 4 months there are northwest winds. They attributed the symmetrical shape of the reefs and the sand accumulation in the reef centre to this shifting wind pattern.

It is noteworthy that bathymetric rises on the Sahul Shelf correspond to areas of shallow Precambrian rocks, and bathymetric depressions to deeper Precambrian rocks (Veers and Van Andel, 1967). There have been few tectonic events in northwestern Australia, thus permitting the shelf morphology to be reflected by the regional structure on the adjacent land. Veers and Van Andel speculate that block faulting has caused the correspondence between the morphologic expression and the structure. It is uncertain whether the magnetic basement lies within or on the Precambrian, or in volcanics of the Lower Cambrian. In any case, a high

in the magnetic basement corresponds in part with the axis of the morphologic Landonderry Rise, both of which are on strike with the Sahul reefs. Thus there is a remarkable coincidence between structure, shelf morphology, and reef growth. A detailed study of the regional structure in the Northwest Territories of Canada may reveal a subtle structural trend underlying the Horn Plateau reef. Such information could be used to locate additional reefs that probably grew on this shelf.

Framebuilders in modern reefs are most prominent in areas which are best exposed to rough water conditions (Kornicker and Boyd, 1962, p. 647; and others). This information and a comparison of the Horn Plateau reef to the Sahul Shelf reefs would suggest that the dominant wind and current direction during development of the Horn Plateau reef was from the northeast, since this quadrant of the reef has the best framebuilding development. A subordinate southwest wind might have been necessary to produce the symmetrical shape and the sand on the reef flat. Figure 8 indicates that the framebuilders have migrated northeast into the prominent wind direction. It is interpreted that the Horn Plateau coral patch reef, like the Sahul Shelf reefs developed on a stable shelf; this shelf being the Anderson - Great Slave shelf (Fig. 3).

The northeastern quadrant of the reef contains a series of knobs which have been referred to as erosional stacks and pillars (McLaren and Norris, 1964, p. 1). Possibly these represent a relict spur and grove system. Maxwell (1968, p. 110) states that such structures are common to all reefs and are best developed on the windward side of the reef.

Sedimentary Textures

Grain size and sorting have been interpreted by many to be a reflection of the kinetic energy that existed in the water at the depositional interface and a few feet above it. For an interpretation of the energy of the depositional environments, Plumley et al (1962) established a genetic limestone

classification. It is comprised of 5 limestone types ranging from quiet water sediments through to strongly agitated water sediments. Sanders and Friedman (1966, p. 197) concluded that this approach is valid but emphasized that biological components as well as physical forces affect turbulence. Sediment grain size is not always, however, a reliable measure of wave energy. Taft and Harbough (1964) and others have observed coarse well sorted sediments accumulating in areas of low wave energy. Therefore, as Bathurst (1967, p. 464) emphasized, "sorting as a measure of turbulence and thus of depth must be treated with great caution.".

Figure 11 illustrates the geographic distribution of the sand sized material on the Horn Plateau reef outcrop surface, based largely on visual estimates in the collected hand samples. The terms 'rare', 'common', 'abundant', and 'very abundant' in the illustration correspond roughly to less than 10, 10 to 40, 40 to 70, and greater than 70 percent, respectively. The error in the visual estimate is believed to be less than 15 percent by volume.

The distribution of the gravel sized material is usually inversely related to that of sand. However, microfacies with large amounts of micrite are exceptions, for example: in the Stachyodes calcirudite, there is rare sand and abundant gravel; in the rudaceous calcilutite, rare sand and common gravel; in the calcilutite, rare sand and gravel.

The reef flat has the largest amount of sand-sized and, correspondingly, the least amount of gravel sized material. Hand samples of the crinoid calcarenite and crinoid skeletal calcarenite may contain as high as 90 percent sand sized material. The calcarenite microfacies are fair to well sorted and would belong to type 4, subtype 4 limestone of Plumley et al (ibid). Of the microfacies on the reef flat, only the Stachyodes calcirudite has a low sand content and a large amount of gravel and mud sized sediment.

Maiklem (1966, pp. 90 - 97), working on the Capricorn reef complex

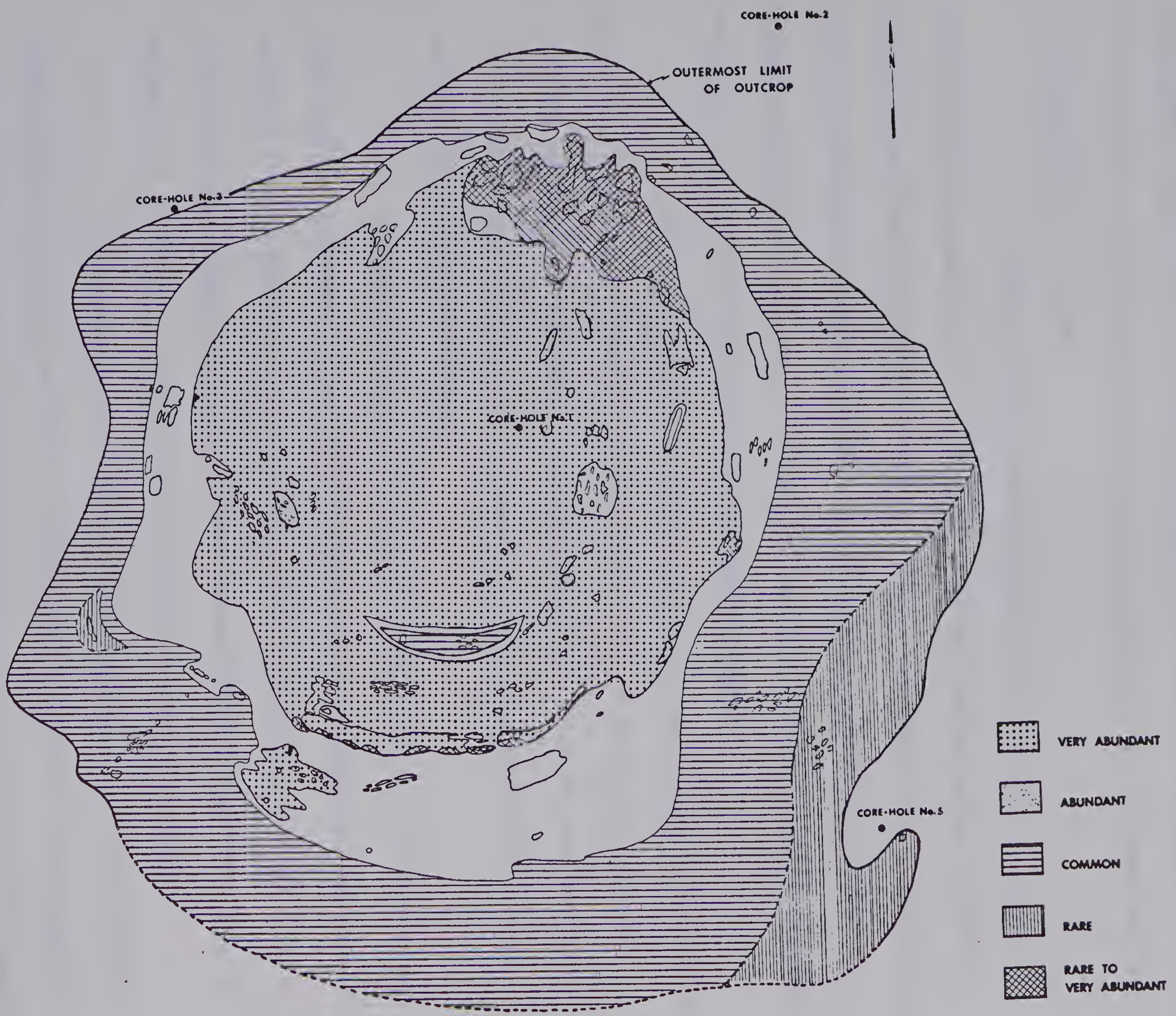


Fig. 11. Distribution of sand sized particles on the Horn Plateau reef surface.

observed that areas with 1 to 2 feet of water over them at low tide, that is the reef flats, have the highest sand content. Wave energy is not sufficient to move much gravel debris from the live coral entanglement on the 10 degree slopes encircling the reef tops, up onto the coral-sparse reef flats, thus mainly sand sized material has accumulated in this area.

It is believed that the Horn Plateau reef flat like the Capricorn reef flat, was an environment of moderately turbulent shallow waters depositing generally well sorted sand sized sediments. The crinoid calcarenite is better sorted than the crinoid skeletal calcarenite due to progressive southwesterly sorting by the dominant northeasterly current. On the reef flat dense thickets of Stachyodes grew and acted as a sediment baffle entrapping micritic material.

The reef flank has less sand and more gravel sized material than the reef flat. Radiating out from the reef flat the amount of gravel sized material increases gradually to a miximum and then diminishes. Only the area outlined by the crinoid and the crinoid skeletal calcarenite on the southern reef flank has very abundant sand sized material.

Maiklem (1966, p. 90) observed the highest gravel content in the Capricorn reef sediments on the fore reef slopes (areas of 10 degree slope encircling reef tops). Coral growth is most rapid here and the high gravel content is due to its proximity to this source; winnowing of fines leaves behind a lag gravel, and, as on the Sahul Shelf reefs, coral shingle accumulates on the reef flanks.

The large amount of gravel sized material on the Horn Plateau reef flank, like the Capricorn reef flank, is interpreted to be due to: 1) proximity to a source of large skeletons - mainly solitary corals; 2) winnowing of fines from this area. The high proportion of crinoid material in the reef flank facies probably was derived from the windward direction. The areas of gravel sized sediments were undoubtedly covered by strongly agitated water (Plumley et al, 1962, type 4,

subtype 4). The crinoid Thamnopora calcirudite is interpreted to be essentially a coral shingle accumulation. Periodic storms probably carried quantities of sand off the reef flat redepositing it on the reef flank.

The organic reef facies contains varying amounts of sand and gravel sized sediments, and inadequate sample control made isoplething of this area impractical. Sorting is poor because of the high percentage of gravel sized fragments of framebuilders that have trapped sand and gravel in their interstices. As on the reef flank, strongly agitated water was probably the normal condition. Control is not sufficient to determine whether or not the postulated windward side has a higher gravel content than the leeward side of the reef.

The rudaceous calcilutite and calcilutite microfacies have 40 to 70 and greater than 80 percent micrite, respectively. If the present topographic expression represents the reef as it was near the ned of reef development, then the depth of water above these microfacies would have been approximately 50 to 75 feet. These 2 units are probably homotaxial to those of the reef flat and organic reef, and developed in only slightly agitated waters. This is the "off reef" material referred to earlier.

Corals

General ecological considerations: There are 2 ecological types of corals: 1) hermatypic, those which live in colonies and form reefs, and 2) ahermatypic or solitary corals. According to Wells (1967) and others, the depth and temperatures of Recent hermatypic Scleractinia corals are influenced by the requirements of their symbiotic zooxanthellae (algae). This restricts them to shallow,

(rarely over 100m), warm (10 to 40° C), and saline (30 to 48 ppt) waters. Ahermatypic corals lack zooxanthallae and usually are not depth controlled but are temperature controlled. This type of coral is presently forming coral mounds in depths below 300 feet and in cold (4° C) waters (Teichert, 1958).

Studying the oxygen isotopes of Cenozoic corals, Wells (1967) concluded that these corals lived under conditions similar to the Recent forms. Tabulata and Rugose corals from the Devonian, however, are extenct, and whether they had symbiotic algae which would be the controlling factor for depth, is not known. Wells found that determining the depth and temperature for Paleozoic corals is not as easy as for Cenozoic forms, but he did conclude, as did Vaughan (1911) and others, that there is no reason to expect different conditions for Paleozoic corals than for Recent ones. Wells agrees with Durham (1950) that the "past ecological requirements of association are similar to those of similar Recent organisms". The Horn Plateau reef is thus assumed to have developed under conditions similar to those outlined above for Recent hermatypic corals.

Geologists and marine biologists have devoted a great deal of attention to the ecology of Recent reefs. Goreau (1959), Kornicker and Boyd (1962), Storr (1964), Adams (1968) and others have observed that coral morphology is affected by physical factors which result in ecologic zones. Generally in deeper waters, massive corals characterised by *Montastrea* and *Siderastrea* flourish; the staghorn and elkhorn corals characterised by *Acropora cervicornis* and *A. palmata*, respectively, are found in shallower, more turbid waters. Goreau (1959), however, observed that the staghorn coral *A. cervi-*

cornis occurs in deeper water with the massive coral _Monastrea_ but that it is not abundant. A similar situation of abundant massive forms living deeper than braching forms probably existed during Devonian reef building.

Horn Plateau reef corals: Corals are the most important framebuilders present in the Horn Plateau reef and are found throughout it (Fig. 12). A discussion of the various shapes of the corallum follows:

Massive and/or Non-Branching Corals - These are characterised by _Alveolites_, _Atelophyllum_, _Australophyllum_, _Chaetetes_, _Favosites_, _Hexagonaria_, and _Utaratuia_, all of which are abundant in the organic reef macrofacies. With the exception of bryozoans these corals are associated with all the other fauna, but are most commonly observed with stromatroporoids.

It is noteworthy that the individual corallites of _Atelophyllum_ grew in contact with one another in the organic reef, but on the reef flat the corallites are solitary. Evidently, in strongly agitated waters individual corallites had to be in contact with one another, probably for added strength.

Alveolites and _Chaetetes_ are usually found together, and where they are abundant, as in the _Chaetetes_-stromatoporoid biolithite, they are commonly associated with _Stromatopora_ and the algal - stromatoporoid consortium _Clathrocoilona_. Branching, phaceloid, dendroid, and solitary corals, if present, are not usually abundant. It is interpreted that _Alveolites_ and _Chaetetes_, like the massive corals _Montastrea_ and _Siderastrea_, discussed above, favored strongly agitated waters but below the zone of surf action. Within the coral biolithite, _Alveolites_, as did _Australophyllum_, _Favosites_, and _Utaratuia_, grew

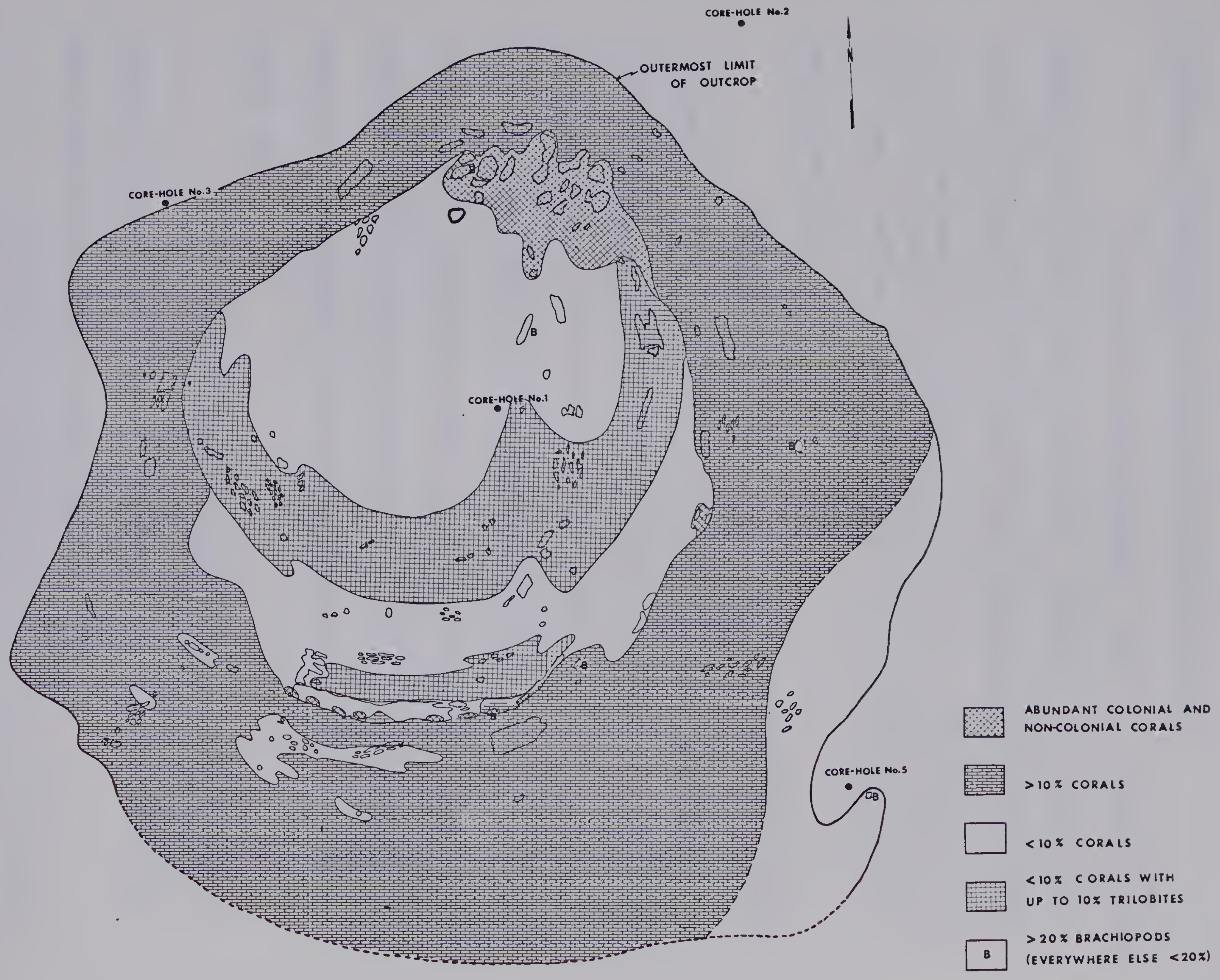


Fig. 12. Coral, brachiopod, and trilobite isopleth map, Horn Plateau reef surface.

where stromatoporoids could not grow. Klovan (1964, p. 39) also observed occurrences of Alveolites not associated with stromatoporoids.

Of the colonial corals, Favosites appears to have been the most adaptable, and is found in all 3 macrofacies. Apparently it was able to grow on a relatively mobile sand substrate in the shallow moderately agitated waters of the reef flat, and in the strongly agitated waters of the organic reef and reef flank facies. The latter facies environment was not favorable to the growth of other colonial corals.

Hexagonaria is rare and occurs only in Core-hole No. 2 within the organic biolithite. It is associated with solitary Neostringophyllum, branching Thamnopora and the massive to tabular stromatoporoids Stromatopora and Trupetestroma. It will be shown in the discussion of branching corals that the waters at this locality were probably deep but strongly agitated. Studying Frasnian reefs in Belgium, Tsien (1967, p. 279) concluded that Hexagonaria was adaptable to different bottom conditions. It is unknown why Hexagonaria was seemingly not so adaptable to the variety of environments within the Horn Plateau reef.

Bushy v-shaped colonies of Australophyllum and Utaratuia are common in the outcrop of the organic biolithite (Pl. I, Fig. 5). Apparently these corals flourished best in strongly agitated waters.

In summary, it is interpreted that the colonial corals generally grew best in relatively shallow, strongly agitated waters where they acted as framebuilders entrapping debris between their lattice-like structures. Some, like Favosites, were very adaptable, living in different types of environments;

others, such as _Chaetetes,_ grew abundantly but only where stromatoporoids were present.

Branching or Ramose Corals: This type of coral is represented by the species _Thamnopora limitaris_. It is an important sediment contributor to the reef and _in situ_ occurrences are most abundant within the biolithite which carries the genus name. Here the branching coral comprises greater than 60 percent of the rock. _In situ Thamnopora_ are associated with _Alveolites,_ an association also observed by Klovan (1964, p. 40), in the coral biolithite in Core-hole No. 2 (Fig. 8) and with _Trupetostroma_ in the underlying biolithite. _Thamnopora_ occurs with a high percentage of micritic material in the _Thamnopora_ biolithite whereas in Core-hole No. 2 it is associated with more sand and gravel sized sediment. Abundant _Thamnopora_ are also present within the dark colored crinoid skeletal calcarenite in Core-hole No. 3. In the underlying "basal" calcilutite in the same Core-hole scattered _Thamnopora_ are present.

There is _Thamnopora_ debris generally throughout the entire reef. It reaches its greatest abundance in the crinoid _Thamnopora_ calcirudite. It has not been definitely established whether _Thamnopora,_ on the reef flat is entirely debris or whether some coralla are in, or near growth position. The writer believes that the latter situation is fairly probable.

In morphologic shape, _Thamnopora_ can be compared to the staghorn corals _Porites_ and _Acropora cervicornis_. As mentioned above, these corals flourish best in shallow turbulent waters. It is interpreted that the _Thamnopora_ biolithite developed under similar conditions.

It is noteworthy that the size of the Thamnopora coralla is different in Core-hole No. 1 than in Core-hole No. 2. Generally they are large - up to 2.5 cm in diameter and 10 cm long within the Thamnopora biolithite, but in Core-hole No. 2 they are smaller - up to 1.5 cm in diameter and 4 cm long. They are also less abundant in Core-hole No. 2.

Goreau (1963) has observed that with increasing water depth branching corals grow thinner and more slender. Apparently, in shallow water natural selection favors corals with thick, heavy skeletons. Goreau (ibid) also observed, however, that corals in shallow shaded environments are similar in growth form to deeper water species. Therefore an erroneous geological conclusion regarding depth-shape relationship for corals could result and caution must be used.

It is interpreted from the size and shape of the coralla in Core-hole No. 2, and from the associated fauna, that Thamnopora developed in this location in deeper less agitated waters than in the Thamnopora biolithite. The branching corals acted as sediment baffles entrapping mud and sand sized sediments.

Murray (1966, p. 19) believes Thamnopora existed in deep or quiet sheltered waters because the coral has a micritic matrix and is associated with tabular stromatoporoids. Lime mud, however, may be entrapped by a sediment baffle and accumulate below overlying turbulent water; therefore, too much emphasis on Leighton's and Pendexter's (1962) grain to groundmass ratio as an indicator of turbulence can be misleading. In addition, tabular stromatoporoids are not always an indicator of deep or quiet sheltered waters.

In conclusion, the interpretation made here is that Thamnopora was exceedingly adaptable, existing in shallow, strongly agitated waters and in both deep and shallow moderately agitated waters on a sand or gravel substrate. Its presence in the "basal" calcilutite infers that it could also live in quiet waters on a muddy substrate. Thamnopora also acted as a sediment baffle. It is proposed that a relatively thick branching coral unit with thick and large coralla should be considered to have developed in shallow strongly agitated waters.

Dendroid Corals - Syringopora, represented by 2 species, S. rockfordensis and S. tubiporoides, is the only dendroid genus present. It is widely scattered but is not quantitatively important. S. tubiporoides is common in the coral biolithite located at the bottom of Core-hole No. 5. Here coral heads up to 6 inches thick occur. This species is also present in the outcrop organic reef (loc. 26) where the heads are 3 inches in diameter. S. rockfordensis occurs sporadically in the crinoid calcarenite, organic biolithite, and rudaceous calcilutite microfacies.

Syringopora is found in mud and sand sized sediment. It is commonly associated with brachiopods, Alveolites, Chaetetes, solitary corals, and stromatoporoids.

The interpretation is that this dendroid coral was able to grow in moderately agitated waters on the reef flat, strongly agitated waters on the organic reef, and in deeper slightly agitated waters within the rudaceous calcilutite. Thus, it withstood a wide variety of conditions, where it acted as

a sediment baffle. Klovan (1964, p. 40) also believed _Syringopora_ lived under quiet to moderately turbulent conditions. He did not, however, specify whether the quiet waters were deep or shallow, nor did he believe that _Syringopora_ lived in strongly agitated waters.

Phaceloid or Subparellel Corals - These are represented by _Disphyllum_, _Sinospongophyllum_, and _Stringophyllum_. The first two occur in all the reefal macrofacies but _Stringophyllum_ occurs only in the organic reef facies. These corals are associated with most of the other faunal groups but no particular genus association is evident. They occur in sand and gravel sized sediments where they acted as sediment baffles. Their relative abundance in the organic reef infers that they flourished best in strongly agitated waters. _Disphyllum_ and _Sinospongophyllum_ were more adaptable than _Stringophyllum_ and could exist in shallow moderately agitated waters on the reef flat as well as in strong agitated waters.

Solitary Corals - Representing this group of corals are: _Buschophyllum_, _Cyathophyllum_, _Cystiphylloids_, _Gryophyllum_, _Heliophyllum_, _Laxanophyllum_, _Neostringophyllum_, and _Siphonophrentis_; the most abundant forms being _Cyathophyllum_ and _Cystiphylloides_. These solitary corals are found throughout the reef with other fauna and are important sediment contributors in the reef flank facies.

Solitary corals were able to withstand moderately agitated waters and flourished on the slopes of the gravel-strewn reef flank. It is interpreted

that some, like Cystiphylloides and Cyathophyllum, because they are common or abundant on the reef flat, were able to grow on a sandy substrate in shallow moderately agitated waters.

Stromatoporoids

This sessile benthos fauna is second only to corals as the most abundant framebuilder present. Massive and tabular forms are present in the organic biolithite on the surface (Fig. 13) and in Core-hole Nos. 1, 2, 3, and 5 (Fig. 8). Tabular forms occur sporodically on the reef flat but only one occurrence was observed in the leeward reef flank. The branching form Stachyodes is found in the outcrop reef flat and in Core-hole Nos. 1 and 5. It is the only stromatoporoid found associated with mud sized material. Stromatopora and Trupetostroma, the most abundant massive and tabular genera present, respectively, occur in both sand and gravel sized sediments. Stromatoporoid debris occurs everywhere on the reef outcrop, usually comprising considerably less than 10 percent of the bulk volume, but, in places, greater than 10 percent. The stromatoporoids are associated with algae, corals, brachipods, crinoid debris, ostracods, conodonts, and Tentaculites.

Stromatoporoids, because they are an extinct group, present a more perplexing problem than corals in the determination of their paleoecology. Many studies have been done on the distribution of the shapes of stromatoporoids (Edie, 1961; Klovan, 1964; Noble, 1965; Murray, 1966; Leavitt, 1968; and others). The general consensus is that massive and branching types favoured shallow turbulent waters while tabular types preferred quiet, shallow to deep

Fig. 13. Crinoid and stromatoporoid isopleth map, Horn Plateau reef surface.

water. There are exceptions, however, to these generalities. Murray (1966, p. 16) observed massive types associated with Amphipora in a mud - textured matrix. Amphipora has been considered by many workers (Klovan, 1964, p. 38; Comeil, 1969, pp. 45-46; and others) to have lived in quiet waters. It would follow that the associated massive stromatoporoids in this case lived in quiet waters. Murray (ibid) did, however, express some uncertainty as to whether or not these massive stromatoporoids were actually in situ. Perkins (1963, p. 1341) believes tabular stromatoporoids favoured shallow turbulent waters and Jamieson (1967, pp. 163-165) envisages branching Stachyodes in agitated but protected shelf areas. A discussion of evidence relating to the ecology of the three most abundant Horn Plateau reef stromatoporoid genera follows:

Stromatopora - This genus is the most widespread and abundant genus present. It is closely associated with the massive corals Alveolites, Chaetetes, and Favosites but rarely with the branching coral Thamnopora. Stromatopora occurs within the rudaceous calcilutite, crinoid skeletal calcarenite, and organic biolithite. Therefore, it was able to withstand slightly agitated waters through to strongly agitated waters; however, it flourished best in the latter environment within the organic biolithite.

The growth form of Stromatopora, in the outcrop, varies. In the organic reef the coenostea is generally massive (Pl. 1, Fig. 6) and may be 20 inches long and 8 inches thick. Tabular forms, however, were observed in this macrofacies at locality 89. Thus the same genus with differing morphologic shape occurs in what appears to be the same general paleo-

environment, that is, strongly agitated waters. On the reef flat, the coenostea of Stromatopora, as well as all other stromatoporoids present with the exception of the branching types, are tabular. Fischbuch (1968, p. 525), Jamieson (1967, p. 156), and others have also observed that morphologic shapes of stromatoporoid genera has been influenced by the environment. Stearn (1967, p. 799; pers. comm., 1969) suggests that possibly stromatoporoid species may be used as indicators of particular paleoenvironments. In this study, distrinction was made only at the generic level, and more detailed work must be done at the species level to evaluate the preceding suggestion.

The presence of Stromatopora on the reef flat indicates that it was able to grow on a relatively mobile substrate. It thus acted as a sediment binder stabilizing the sediments. Dumestre and Illing (1967, pp. 337-338) also believe Stromatopora acted as a sediment binder. Jamieson (1967, p. 155), however, believes that stromatoporoids were unable to grow upon an unstable substrate of mud or sand. Stromatopora, besides growing on crinoid and other skeletal debris, was able to encrust corals.

In summary, it is interpreted that in strongly agitated waters the growth form of Stromatopora was generally massive; in moderately agitated waters it was tabular. Stromatopora lived in different water depths, but flourished best in strongly agitated waters. It was able to act as a sediment binder as well as being able to build wave resistant structures.

Trupetostroma - This genus is abundant in both the reef flat and windward reef flank but is rare in the organic reef. It is associated with

Hexagonaria, Favosites, and Thamnopora. On the reef flat only tabular forms were observed. In Core-hole No. 2 this genus occurs from 213 - 214.8 feet, but due to the small core diameter its shape is unknown.

Its dominant tabular shape, and infrequency on the organic reef are interpreted to indicate that Trupetostroma favoured moderately agitated waters on the reef flat, and deeper waters below the more strongly agitated reef flank. Jamieson (1967, p. 159) also believes Trupetostroma preferred less exposed areas on the platform shelf.

Stachyodes - In outcrop, the Stachyodes calcirudite (Pl. 8, Fig. 5) outlines the area of occurrence for this branching coenostea (Fig. 7). Acting as a sediment baffle Stachyodes entrapped micritic material in this area and it is interpreted that Stachyodes at these localities preferred moderately turbulent waters. No branching stromatoporoids were observed in the more turbulent water conditions postulated for the outcrop organic reef.

In the subsurface, Stachyodes is found within: 1) organic biolithite in Core-hole No. 3; 2) coral - Stachyodes biolithite in Core-hole No. 1; and 3) Stachyodes calcirudite in Core-hole No. 5. In these positions Stachyodes is associated with corals - Atelophyllum, Chaetetes, Disphyllum, Stringophyllum, and stromatoporoids - Stromatopora and other tabular forms which are unidentifiable.

The presence of Stachyodes with the other framebuilders in the biolithite indicates that in this case Stachyodes was able to grow in strongly agitated waters on the slopes of the organic reef. The Stachyodes calcirudite

in Core-hole No. 5 is interpreted to have developed behind the actively growing organic reef in moderately agitated waters. The branching stomatoporoid thicket acted as a sediment baffle entrapping the sand sized crinoid debris that had been transported into this area.

In summary, Stachyodes was found in positions which are interpreted to be on the slopes of the organic reef where water conditions were strongly agitated. This agrees with the general belief that branching forms preferred turbulent waters on the reef slopes. Stachyodes was, however, also able to thrive in what is interpreted to be shallow, moderately agitated waters on the reef flat.

Algae

Algae are recognized in every macrofacies of the reef. Although these plant remains do not appear to be of volumetric importance they probably played a significant role in the building and binding of the reef sediments. Possibly a more extensive petrologic examination would indicate greater abundance.

Clathrocoilona, an alga - stromatoporoid consortium according to Stearn (1966, p. 46), is found in the Chaetetes stromatoporoid biolithite. It is associated with Alveolites and Chaetetes (Pl. 3, Figs. 5 and 6). A blue-green alga Sphaerododium? (Pl. 5, Fig. 10) and algal tubes (Pl. 5, Fig. 7) occur in the crinoid - coral calcirudite of the leeward reef flank. The former bead - like genus, is found in most of the reef facies in the Devonian Canning Basin reefs in Australia (Wray, 1967). Sponge - like algal grains (Pl. 5, Figs.

11 and 12) occur in the reef flat macrofacies. Within the same facies there are examples of what appear to be algal encrustations on skeletal material (Pl. 5, Fig. 1). Two problematic algal forms occur in the windward reef flank (loc. 21); one is massive, exhibiting little internal texture (Pl. 5, Fig. 6), the other has a "laced" appearance (Pl. 5, Fig. 2) and probably acted as a sediment binder.

Radiospheroid calcispheres (Pl. 5, Figs. 4 and 5) occur scattered throughout the reef. Wray (ibid, p. 47-48) and others believe that they are plant spores or reproductive bodies.

Algae can live only in waters penetrated by light; therefore their presence indicates that the reef sediments were deposited in "shallow" waters.

Crinoids

Disarticulated crinoid ossicles are the most abundant sediment component in the Horn Plateau reef. Crinoid content is greatest on the reef flat where usually crinoid ossicles comprise 70 percent of the crinoid calcarenite. The crinoid content is less on the outermost periphery of the reef (Fig. 13) where the micrite content is high, e.g., in the calcilutite microfacies.

The energy level of the reef is interpreted to have been too high for the crinoids to have existed there. A more favorable environment would have been to the windward on a muddy bottom. From this position the columns could have been transported onto the reef during storm activity. The gravel sized ossicles were trapped in the coral entanglement on the reef flank, and

the fines were further winnowed onto the reef flat.

Brachiopods

This sessile fauna is ubiquitous in the reef outcrop (Fig. 12). Nearly everywhere there is between 5 and 20 (usually approximately 10) percent brachiopods in the sediments, but the leeward reef flank is comprised of less than 5 percent and minor areas have 20 percent. These latter rocks are designated as the brachiopod calcirudite. Field observations of the brachiopods indicated that all the shells are closed and unoriented. The fauna occurs in mud, sand, and gravel sized sediments. No particular close association with any other fauna is apparent. The most abundant species are: Ambocoelia cf. A. umbonata, Atrypa nasuta, Camarotoachia, Cranaera?, and Spinatrypa hornensis.

The abundant species, with the exception of Camarotoechia, are found in differing types of facies. It can be inferred that these withstood a "considerable" range of environmental conditions. The rhynchonellid Camarotoechia is restricted to the crinoid calcarenite microfacies. This species apparently preferred a sandy bottom in moderately agitated waters. The brachiopods whose occurrences are designated as 'rare' may include only one speciment, so no environmental conclusion is attempted. If preservation was equal in all cases, growth conditions were not favorable for these brachiopods. It can be inferred that the brachiopods found in this study lived in generally turbulent shallow waters.

Atrypa nasuta, Camarotoechia, and Craneana? cryptonelloides are abundant throughout the majority of the reef flat outcrop microfacies. The

costellae of A. nasuta and Camarotoechia are prominent, but are lacking on Cranaena? cryptonelloides. Apparently the amount of brachiopod ornamentation cannot be used as an indicator of turbulence in this microfacies. Ager (1963, p. 133) has also observed different types of ornamentation in the same brachiopod assemblage.

The differing environments existing throughout the reef resulted in several types of brachiopod calcirudites. In the organic reef the calcirudite lies sharply against the biolithite (Pl. 1, Fig. 3). The brachiopods are not fragmented and are interpreted to have been swept by current action in this strongly agitated water zone a short distance into a depression. Such cavities probably resulted from scouring or existed between framebuilding organisms.

In the reef flat the brachiopod calcirudite is encircled by the crinoid skeletal calcarenite. The strong-ribbed Atrypa nasuta brachiopods are believed to have lived on the reef flat and accumulated by wave action under the moderately agitated water conditions.

The brachiopod calcirudite at locality 16B in the reef flank is encircled by the calcilutite microfacies. The pebbles of the calcirudite are smooth shelled Cranaena? brachiopods; the matrix is micrite. These brachiopods are interpreted to have lived on a muddy bottom in only slightly agitated water and not to have been transported any appreciable distance.

In conclusion, favorable conditions prevailed for brachiopod growth. Most widespread are the atrypids - Atrypa and Spinatrypa and the spirifirids - Ambocoelia, Emanuella, and Eleutherokomma, both of which

generally favoured moderately to strongly agitated waters. Smooth or pominent ornamentation by itself should not be considered a measure of wave energy.

Trilobites

Trilobites (Dechenella) may comprise 10 percent of the rock volume. They occur in a restricted area in the reef flat outcrop macrofacies (Fig. 12). Only pygidium and glabella fragments were observed within the crinoid calcarenite and crinoid skeletal calcarenite microfacies. Separate microfacies varieties were established to delineate their presence.

Trilobites flourished in the Lower Cambrian, reached their climax in the Upper Cambrian, steadily declined after this and became extinct by the end of the Permian. These largely vagrant benthos dwellers apparently were adapted to a wide range of marine environments (Shrock and Twenhofel, 1953, pp. 579-604), and did exist on Silurian reefs of the Michigan basin (Ingles, 1963, p. 415; Lowenstam, 1957, p. 232).

In the Horn Plateau reef, no trilobite specimens were observed with the dorsal and ventral structures preserved. The interpretation is that these fossils are molts which floated onto the reef and settled on the sandy bottom. Turbulence was too great immediately behind the organic reef to allow the molts to be deposited, consequently they were carried down current into the less agitated waters of the reef flat. The apparent absence from the reef flank implies that here too, turbulence was too high for their deposition. A favorable living area for the trilobites would have been windward on a muddy bottom in deeper, quieter waters.

Pelecypods

Pelecypods are rare in the Horn Plateau reef as only 2 specimens (Conocardium and Leptodesma) were recovered. These were found in one outcrop (loc. 22A, Fig. 2) in the northeast quadrant of the reef flank. They are associated with brachiopods, crinoids, and corals within gravel sized sediments, the crinoid-coral calcirudite.

This rock type is interpreted to have formed in strongly agitated waters. If these pelecypods are in their place of habitat, and it is uncertain whether they are, then they preferred this type of environment.

The scarcity or absence of pelecypods has been noted in other Devonian reefs (Kloven, 1964, p. 40; Murray, 1966, p. 21; Pfaff, 1967, p. 36; and others).

Gastropods

Gastropods contribute less than one percent to the Horn Plateau reef limestones. They occur sporadically in all 3 outcrop macrofacies, and the identified species, which are all of about equal abundance, include: Ceratopea? Mastigospira, Platyceras, and Straparollus. Ceratopea? occurs in the crinoid - coral calcirudite and the other 3 occur in the crinoid skeletal calcarenite. It is inferred that these latter 3 favoured living on a sandy bottom in moderately agitated waters, while Ceratopea? preferred strongly agitated waters.

Bryozoans

Fenestellid bryozoans occur in the windward reef flat in the

rudaceous calcilutite, calcilutute, and brachiopod calcirudite microfacies. They comprise less than one percent of the limestones. Their position in the reef implies that they lived in deep, slightly agitated waters.

Conodonts

Conodonts are located in all of the macrofacies but contribute less than one percent to the reefal limestones. It is unknown if they lived on, or were transported onto, the reef.

Ostracods

This nektonic - planktonic fauna contributes less than one percent of the sediments within the Horn Plateau reef. Specimens occur in all 3 reef macrofacies. Rozhdestrenskayites (identified by B. Cameron) is a common form. The observed specimens were usually found with sand sized crinoid material. They probably were transported after death and their presence is not a good environmental indicator.

Tentaculitids

These narrow conical shaped benthonic to planktonic fossils of uncertain affinity (Fisher, 1962, p. W102) are found in all 3 of the macrofacies. One collected hand sample (loc. 28) is comprised of 90 percent of 4 - 4.5 mm long Tentaculites, but usually there are less than one percent. They occur with all the other fauna in sand and gravel sized sediments. It is not known whether they lived on the reef or in a forereef position.

Biotopes

The preceeding has been a consideration of the paleoautecology, that is, the paleoecology of the individual organism or group. The following is a discussion of the paleoecology of the community or what is commonly referred to as paleosynecology.

Seven biotopes or associations of organisms characteristic of a particular geographic setting are outlined. Proceeding from a deeper off reef position up onto the reef flat these are: 1) crinoid, 2) bryozoan, 3) solitary coral, 4) massive coral and stromatoporoid, 5) *Thamnopora,* 6) brachipod, and 7) *Stachyodes*. These biotopes, with slight variations, probably were repeated going in a leeward direction. Firgure 14 illustrates these associations, but a scaler cross-sectional relationship is not intended.

Crinoid biotope - This biotope is located in an off-reef position where it is interpreted to have developed in relatively deep, intermittently agitated waters. It has been established to simply roughly indicate the region where the crinoids probably grew. Although this biotope was not observed in outcrop, the "basal" calcilutite is believed to closely approximate the lithology. On the muddy bottom, in which the organic content was no doubt high, scattered *Thamnopora,* solitary corals, brachiopods, and gastropods are interpreted to have grown within the crinoid "meadows". This is probably the biotope in which the ostracods and trilobites also thrived best. It is believed that the disarticulated crinoid ossicles as well as the ostracods and trilobites within the reef were derived from this position.

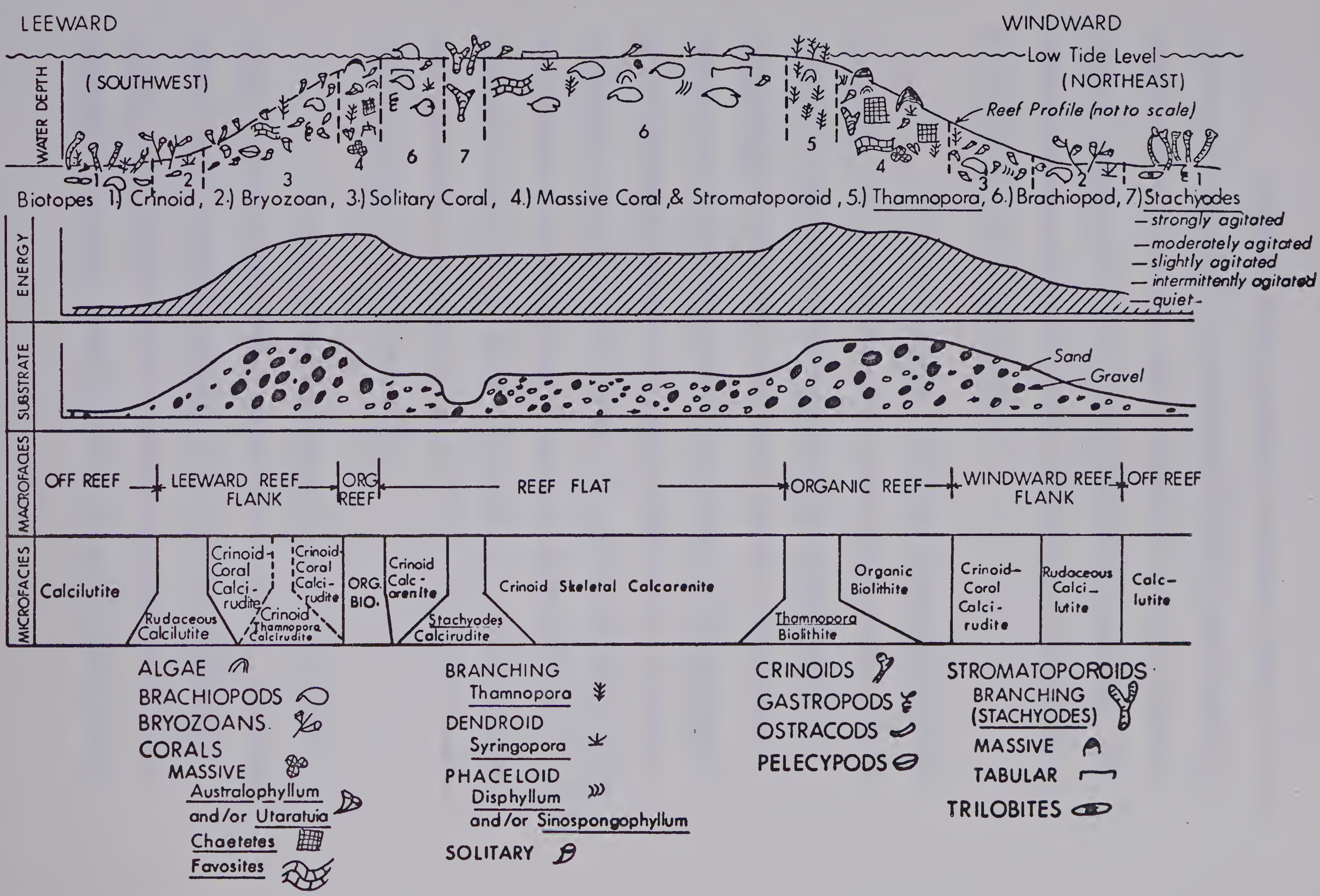


Fig. 14. Idealized cross section showing distribution of biotopes, Horn Plateau reef.

Bryozoan biotope - Located on the outermost slopes of the reef, this biotope is interpreted to have developed in slightly agitated waters at depths too great fro hermatypic corals. Fenestillid bryozoans, brachiopods, dendroid - Syringopora and solitary corals contributed to the biotope. The substrate consisted predominantly of mud, but sand and gravel sized rubble, derived from the reef, was also present.

Solitary coral biotope - Progressing up the slope of the reef the energy level of the water increased to more strongly agitated conditions, and solitary corals, characterised by Atelophyllum, Cyathophyllum and Cystiphylloides, are believed to have grown in profusion. The hardy and adaptable massive Favosites and the tabular stromatoporoid Trupetostroma as well as brachiopods, gastropods - Ceratopea, pelecypods, and branching Thamnopora are also found in this biotope. The substrate consisted predominantly of gravel and sand sized crinoid, coral, and stromatoporoid debris. This accumulation resulted in the crinoid - coral calcirudite. Locally occurring coral shingle debris on the slopes of the reef flank resulted in what is now the crinoid Thamnopora calcirudite microfacies.

Massive coral and stromatoporoid biotope - This biotope represents the most complex faunal association within the reef. Massive coral characterised by Alveolites, Atelophyllum, Australophyllum, Chaetetes, Favosites, and Utaratuia as well as the massive Stromatopora and branching Stachyodes are abundant. Other fauna within the biotope consist of algae,

brachiopods, Syringopora, Thamnopora, phaceloid and solitary corals.

It is interpreted that shallow, strongly agitated water conditions prevailed. The bottom was covered by coral thickets that entrapped sand and gravel sized debris. The organic biolithite is the resulting rock type. Locally, conditions favoured the growth of either corals or stromatoporoids, perhaps due to slight variations in available food, depth, or turbulence.

Thamnopora biotope - This branching coral, which must have grown as lush thickets, characterises this biotoype. Algal material is found associated with Thamnopora. The interpretation is that this biotope developed up-slope from the massive coral and stromatoporoid biotope in shallow strongly agitated waters. The bottom sediments ranged from mud to gravel sized. Thamnopora, like Stachyodes, acted as a sediment baffle entrapping the finer micritic and calcarenitic material. The resulting rock type is the Thamnopora biolithite. Because it is unknown whether this biotope developed on both the windward and leeward side of the reef, it is placed only on the windward side in Figure 14.

Brachiopod biotope - This biotope, located on the sandy substrate of the reef flat, and interpreted to have existed in moderately agitated waters, is characterised by the presence of brachiopods (particularly Atrypa), algae, Disphyllum, Syringopora, Thamnopora, and solitary corals (particularly Cystiphylloides); to a lesser degree colonial corals, stromatoporoids, and gastropods also grew. Of the colonial corals, only the adaptable massive

Favosites was able to exist. Tabular stromatoporoids particularly *Stomatopora* and *Trupetostroma* spread over the sediments binding them together. Debris from the organic reef facies, and trilobite molts and ostracod carapaces from the crinoid biotope spread out onto the reef flat. The resulting rock types are the crinoid and crinoid skeletal calcarenites. It is noteworthy that the brachiopod population was probably no higher on the reef flat than on either the organic reef or the reef flank, but fauna other than the brachiopods did not flourish in this environment.

Stachyodes Biotope - The branching stromatoporoid *Stachyodes* characterises this biotope. Brachiopods and *Thamnopora* found in the resulting *Stachyodes* calcirudite may have lived with *Stachyodes*. Located on the shallow water reef flat behind the actively growing massive corals and stromatoporoids, this biotope grew under what is interpreted to be only moderately agitated conditions. In this position *Stachyodes* acted as a sediment baffle entrapping micritic as well as sandy crinoid material.

CORRELATION AND AGE RELATIONSHIP

McLaren and Norris (1964) discussed the age of the Horn Plateau Formation. Determining its age was difficult as many of the species were new and therefore could not be correlated with other faunas. The corals, McLaren (ibid, p. 5) stated, suggest a mid - to - late Givetian age. Norris (ibid, p. 31) tentatively assigned the Horn Plateau Formation to the very late Givetian. He suggested that it would be broadly equivalent to, or younger than, the

Sulphur Point, Presquile, and Kee Scarp Formations, and slightly older than the basal Waterways Formation.

The present writer follows the succession of fossil assemblages set up by Warren and Stelck (1950, 1956). The assemblages which are pertinent to the Horn Plateau Formation in descending stratigraphic succession are:

Leiorhynchus castanea (=*Caryorhynchus*)

Cyrtina panda

Stringocephalus burtini

Rensselandia laevis

Ambocoelia meristoides

Radiastraea arachne

Identification of the additional fauna collected from the Horn Plateau Formation (Table 3) indicates that certain species are included by Warren and Stelck (1956) in the above assemblages. These species and their appropriate assemblages are:

S. burtini: *Gypidula* cf. *G. comis*, *Schizophoria manitobensis*, *Mastigospira* sp., and *Thamnopora limitaries* (=*Favosites limitaris*)

A. meristoides: *Emanuella* cf. *E. meristoides* (=*Ambocoelia*), *Leiorhynchus* cf. L. *awokanak* (=*Nudirostra*), and *Favosites alpenensis*.

R. arachne: *Thamnopora limitaris* (=*Favosites limitaris*)

The presence of these species permits correlation of the Horn Plateau Formation to its equivalents. Reference to the correlation chart of Givetian Formations (Table 2) will aid the reader in the discussion of each of the fossil assemblages.

Radiastraea arachne fossil assemblage: *Thamnopora limitaris* is common to both the *R. arachne* and to the *Stringocephalus burtini* assemblages. This species thus has a relatively long time span and its presence can only infer a Givetian age for the Horn Plateau Formation.

Ambocoelia meristoides fossil assemblage: Caldwell (1967) gives the range of *Emanuella meristoides* from the uppermost Eifelian to the upper middle Givetian. This species has been found in the uppermost Chinchaga Formation and above the upper middle Pine Point Formation in the Great Slave Lake region. In the lower Mackenzie River Valley it has been found from the middle of the Hume Formation extending through the Hare Indian Formation and up to the middle of the Ramparts Formation. Warren and Stelck (1956) include *Leiorhynchus awokanak* (=*Nudirostra*) in the fauna from the Pine Point limestone and *Favosites alpenensis* from the Hare Indian shale. The occurrence of these 3 species in the Horn Plateau Formation infers that the reef is broadly equivalent to the Pine Point, Hare Indian, and Ramparts Formations.

Rensselandia laevis fossil assemblage: No species from this assemblage were identified in the Horn Plateau Formation. Norris (McLaren and Norris, 1964, p. 29), however, states that *Atrypa nasuta* superficially

resembles Atrypa cf. A. pechiensis (Grabau). The latter species were recorded from the lower part of the Ramparts Formation by Warren and Stelck (1950, p. 75) and is included in the Resselandia laevis fossil assemblage. Thus there are species in the Horn Plateau Formation which at least resemble fauna from successive stratigraphic fossil assemblages, suggesting that there was probably continuous deposition on the reef.

Stringocephalus burtini fossil assemblage: Norris (McLaren and Norris, 1964) includes Hypothridina cameroni in the brachiopods from the Horn Plateau Formation. The Sulphur Point Formation also carries this species (McLaren et al, 1962, Pl. 9, Figs. 27 - 30). Including Hypothyrinda cameroni, there are 5 species of the Stringocephalus burtini assemblage that resemble species from the Horn Plateau Formation.

According to McCammon (1966) the Dawson Bay Formation carries Schizophoria and Mastigospira alata. Warren and Stelck (1962, p. 279) correctly point out, however, the McCammon's figured specimen (Pl. 8, Figs. 8 - 9) is Schizophoria manitobensis and not S. iowensis; the former as figured by Whiteaves (1892, Pl. 37, Figs. 3 - 5a). Further confusion resulted when Norris incorrectly called S. manitobansis, S. fasciostella (McLaren and Norris, 1964, Pl. 13, Figs. 2 - 4). Mastigospira sp. form the Horn Plateau Formation superficially resembles M. alata from the Dawson Bay Formation. Both M. alata and S. manitobansis also occur in the uppermost part of the Ramparts limestone (Warren and Stelck, 1962, p. 279). Thus there is a strong suggestion that the Horn Plateau Formation is correlative to the upper Ramparts and Dawson Bay Formations.

Two other species are noteworthy: 1) Utaratuia cf. U. laevigate, 2) Ambothyris sp. The former species occurs within the Billingsastraea verilli zone of Chrickmay (1960) which includes the upper beds of the basal Devonian limestone, that is, uppermost Hume Formation. The present writer believes that this species is longer ranging than originally thought, and that the Hare Indian and lower Ramparts may carry this species. Ambothyris sp. resembles the species which occurs within the Kee Scarp Formation as figured by Warren and Stelck (1956, Pl. 15, Figs. 28 - 31). Either this species is longer ranging or this formation is placed too high in the stratigraphic column.

The writer agrees with Warren and Stelck (1962, p. 276), Norris (1965, p. 45) and others that the lower portion of the Horn River Formation is equivalent to the upper portion of the Pine Point Formation. The limestone beds which overlie the Horn River shale and crop out 11 miles northwest of the reef carry a Leiorhynchus castanea (=Caryorhynchus) fauna suggesting that these beds are equivalent to the upper Pine Point Formation (Norris, 1965, pp. 44 - 45). The L. castanea faunal assemblage of Warren and Stelck (1962) is earlier than the 4 assemblages previously discussed. This infers that the Horn River shale underlying the limestone beds would carry an equivalent to the Cyrtina panda fauna, which in turn is underlain by the Stringocephalus burtini and overlain by the Leiorhynchus castanea faunal assemblages. This would indicate that no major hiatus exists between the Horn Plateau and the Horn River Formations.

A single specimen of the two-holed crinoid Gasterocoma? was recovered at 357 feet in Core-hole No. 3. Johnson and Lane (1969, pp. 70 and 73) reported the first occurrence outside western Europe of Gasterocoma and

assigned its range from upper Emsian to Eifelain. Nelson (1965, p. 19) also regards crinoid stems with two axial canals as Lower Devonian. However, two-holed crinoids, although rare, also occur in the type Ramparts Formation (C. R. Stelck, pers. comm., 1969) which is Givetian, and the occurrence of Gasterocoma? in the Horn Plateau Formation is not significant at this time.

In summary, the Horn Plateau Formation is equivalent to the Dawson Bay to the upper Ramparts, and to the middle Pine Point Formations. No major hiatus exists between the reef and the "overlying" Horn River shale. Conodonts recovered from the breccia unit from 63 - 67 feet in Core-hole No. 1 resemble species from the hermanni - cristatus zone which is a zone between the Middle and Upper Devonian in Germany (C. A. Polluck, pers. comm., 1969). Thus, during very late Givetian time there was infilling of material from above, into a deep fracture within the Horn Plateau reef.

GEOLOGICAL HISTORY

During the late early Givetian in the southwestern part of the Northwest Territories a transgressive sea spread out over the Anderson-Great Slave Shelf. Open marine limestones with crinoids, brachiopods, and corals of the Lonely Bay and Pine Point and equivalent Formations carrying the Ambocoelia meristoides fauna were deposited. This ended the evaporitic conditions that had prevailed during the deposition of the Chinchaga and Bear Rock Formations.

Towards late Lonely Bay time renewed uplift of the Tathlina High caused a restriction of the sea in northern Alberta. Increased salinity

killed the reefs that had been actively growing in the Rainbow Basin and produced evaporites (McCamis and Griffith, 1967, p. 442).

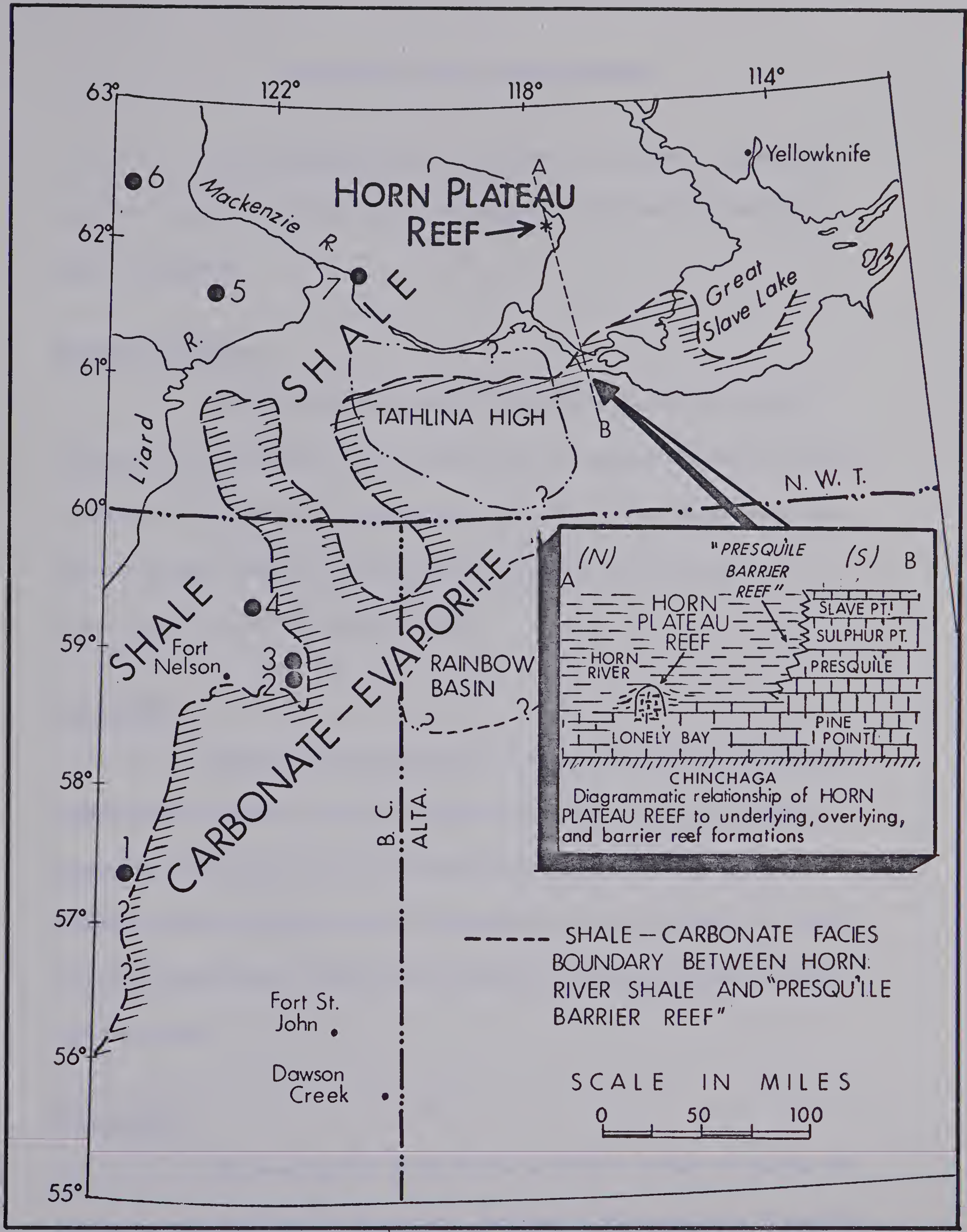
In the marine area immediately northwest of the Tathlina High, subsidence lessened and reef builders gained a foothold in the unconsolidated mud. The Horn Plateau reef began its growth and was to carry a fauna that resembles those from the Stringocephalus burtini fauna assemblage. It is interpreted that subsidence continued and the reef grew upward and in a northeasterly direction. The exact reason for termination of reefal growth is not known. An interesting possibility is that there was a change in the oceanic circulation due to a barrier reef developing to the southeast and southwest and which was contemporaneous with the Horn Plateau reef. This carbonate unit which has been referred to as the "Presquile Barrier Reef" (Basset and Stout, 1967, p. 740) and the Shekile Barrier (McCamis and Griffith, 1967, p. 452) extends from Great Slave Lake to the Rockies of northeastern British Columbia. Except for minor periods of emergence, carbonates were deposited from Pine Point time extending through the Presquile and Sulphur Point and up to and including the Slave Point Formations. This change in marine circulation may have brought adverse conditions (shortage of food, unfavourable water chemistry, etc.) to the taxa and resulted in their death.

Following deposition of the Horn Plateau reef, the argillaceous Horn River Formation was laid down. The shales encroached upon the reef and probably buried it. During the deposition of shale, wave energy in the immediate vicinity of the reef was low. Supporting evidence for this is the

well laminated nature of the shales and the fact that there is only one occurrence of reef rubble in the shale; (this is a 1/2 inch crinoid layer in Core-hole No. 4 at 234 feet).

The Horn River Formation "shales out" along the Presqu'ile Barrier Reef. The facies boundary of the shale with the Pine Point limestones is gradational, but is more abrupt with the Sulphur Point and Slave Point carbonates (Griffin, 1964, p. 13). In outcrop 11 miles northwest of the Horn Plateau reef the Horn River shale underlies limestone beds. These beds are the equivalent of the uppermost Pine Point limestone in the vicinity of Great Slave Lake, as both carry a Leiorhynchus castaena fauna, and may represent a limestone tongue from the "barrier reef".

It is noteworthy that other "reefs" besides the Horn Plateau reef developed north of the "barrier reef" on strata equivalent to the Lonely Bay Formation (Fig. 15). These include the subsurface "reefs" of A - 1 Komie (Richmond, 1965, p. 108), Yoho and Sierra (Griffith, 1967, p. 824) and in outcrop at Redfern Lake (Warren and Stelck, 1962, p. 280). In the Northwest Territories there are the subsurface Camsell A - 37 and the Jean Marie B - 48 'reefs' (R. L. Pemberton, pers. comm., 1969) and the outcropping Root River reef (Warren and Stelck, 1962, p. 276). These "reefs" rest on the Lonely Bay or equivalent strata and are overlain by the Horn River, or equivalent, shale. All the above mentioned subsurface carbonate build-ups in British Columbia are either producing or have tested gas. It is suggested that further drilling will locate additional reefs in front of the shale-carbonate facies contact.



after Griffin, 1965 and 1967

Fig. 15. Other "reefs" with a stratigraphic position similar to the Horn Plateau reef. 1.) Redfern Lake outcrop, 2.) Sierra, 3.) Yoho, 4.) A-1 Komie, 5.) Camsell A-37, 6.) Root River outcrop, 7.) Jean Marie B-48.

SUMMARY AND CONCLUSIONS

The stratigraphy of the Horn Plateau Formation, a carbonate body that crops out in the District of Mackenzie, Northwest Territories has been investigated.

Distinctive Features

The Horn Plateau Formation attained a thickness of at least 402 feet and is classified as a coral patch reef. In outcrop the reef is circular in shape with a diameter of approximately 0.5 miles. Since development the reef has escaped extensive dolomitization. This reef is the only known occurrence of the Horn Plateau Formation.

Petrography

Textural features and types of organisms allowed 3 macrofacies (organic reef, reef flat, and reef flank) and 11 microfacies to be outlined. Generally, the organic reef is characterised by coral and stromatoporoid biolithites; the reef flat by crinoid calcarenites; and the reef flank by crinoid and coral calcirudites, although further along the outcrop periphery calcilutites are present.

Paleontology

An investigation of the fauna revealed a number of species not previously reported from this formation. Included in this group are: 8 brachiopods, 12 corals, 1 echinoderm, 4 gastropods, 1 pelecypod, stromatoporoids,

algae, bryozoans, conodonts, ostracods, and tentaculitids.

Paleoecology and Paleoenvironment

Wave energy varied across the reef. The organic reef and reef flank macrofacies developed in strongly agitated waters whereas the reef flat developed in moderately agitated waters. It is interpreted that the dominant wind was from the northeast with minor occurring southwesterly winds. The Horn Plateau reef is analogous to the Sahul Shelf reefs developing off Western Australia.

Conditions during development of the reef allowed for prolific growth of massive corals - *Alveolites*, *Chaetetes* and *Favosites* and branching *Thamnopora*. These as well as massive stromatoporoids generally developed in strongly agitated waters whereas tabular stromatoporoids like branching *Stachyodes* existed in shallow or deep, moderately to strongly agitated waters. It is concluded that *Favosites* and *Stromatopora* were very adaptable genera. Establishment of the paleosynecology of each organism or group permitted 7 biotopes, each characterised by particular organisms and developing in specific geographic locations, to be outlined. Form an "off reef" position up onto the reef these include: 1) crinoid, 2) bryozoan, 3) solitary coral, 4) massive coral and stromatoporoid, 5) *Thamnopora*, 6) brachiopod, and 7) *Stachyodes*.

Age and Correlation

On the basis of the additional fauna collected from the reef it has been concluded that the earlier assigned very late Givetian age for the

Horn Plateau Formation is not valid. The reef carries a fauna that elsewhere is associated with *Stringocephalus burtini* although this Givetian index fossil is not known from the Horn Plateau reef itself. The Horn Plateau Formation should be considered middle Givetian in age. It is correlated with the middle Pine Point of the south shore of Great Slave Lake and upper Ramparts Formations of the type area on the lower Mackenzie River. It is older than the Sulphur Point and Presqu'ile Formations and probably younger than the Keg River Formation.

Geological History

The Horn Plateau reef developed on or within the Lonely Bay Formation north of the "Presqu'ile Barrier Reef". Reefal development may have terminated when this "barrier reef" caused a change in marine circulation resulting in condition unfavourable for organic growth on the Horn Plateau reef. Following reefal growth, shale of the Horn River Formation was deposited.

Economic Considerations

The best porosity of the reef exists in the reef flank calcirudites and reef flat calcarenites due to the interskeletal porosity between crinoid particles and intraskeletal porosity within the corals. In the organic reef biolithite, calcite cement has obliterated much of the original porosity resulting in the poorest porosity throughout the reef. Other "reefs" in a stratigraphic position similar to the Horn Plateau reef and also north of the "Presqu'ile Barrier Reef" are producing gas in northeastern British Columbia. It is not

unreasonable to assume that other such reefs will be discovered with further drilling. Studying such factors as tectonism, basement structure, and behavior of anomolously high radioactive units of the Horn River shale may prove useful in finding these reefs.

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PLATE I

Horn Plateau reef outcrop

Fig. 1. PILLAR EROSIVE feature of the organic reef macrofacies showing organic biolithite microfacies overlain by a debris bed – crinoid – coral calcirudite; location 90.

Fig. 2. FLAGGY WEATHERING of the crinoid skeletal calcarenite microfacies; location 91.

Fig. 3. BRACHIOPOD CALCIRUDITE microfacies in contact with organic biolithite in the organic reef macrofacies; location 103.

Fig. 4. INTERTONGUING RELATIONS of the massive organic biolithite and flaggy weathering reef flank macrofacies; location 102.

Fig. 5. *IN SITU* THICKET of colonial corals *Australophyllum* or *Utaratuia* comprising a 6 foot bed in the coral? biolithite of the organic reef macrofacies; location 99.

Fig. 6. RUBBLE OUTCROP typical of the reef flat macrofacies; location 42.

Fig. 7. *IN SITU* MASSIVE STROMATOPOROID *Stromatopora* within the organic biolithite of the organic reef macrofacies; location 96.

PLATE I.

PLATE 2

Horn Plateau reef fossils

Fig. 1 — Leptagonia? rhomboidalis (Wilckens), x 1, location 22A, pedicle view.

Figs. 2 - 7 — Ambothyris sp., x 2, location 38, 2 - 5) pedicle, brachial, lateral, and posterior views, 6 - 7) pedicle and brachial views.

Figs. 8 - 15 — Atrypa nasuta Norris, x 1, 8 - 10) pedicle, brachial, posterior, and lateral views; location 10, 12 - 15) pedicle, brachial, posterior, and lateral views; location 3.

Figs. 16 - 17 — Atrypa nasuta hearnei Norris; x 1; pedicle, brachial, lateral, and posterior views; location 49.

Figs. 20 - 21 — Camarotoechia sp.; x 3, pedicle and anterior views, location 80.

Figs. 22 - 24 — Cranaena? sp.; x 2; pedicle, brachial, and lateral views; location: Core-hole No. 3, 83.6 feet.

Figs. 27 & 28 — Ambocoelia cf. A. umbonata (Conrad); x 3.2; juvenile; pedicle and brachial views; location 7.

Figs. 29 - 30 — Emanuella sp.; x 1; pedicle and brachial views; location 12.

Figs. 31 - 34 — Emanuella cf. E. meristoides Meek; x 1; pedicle, brachial, posterior, and lateral views; location 16B.

Figs. 35 - 36 — Gypidula cf. G. comis (Owen); x 1; juvenile; pedicle and brachial views; location 16B.

Figs. 37 - 40 — Leiorhynchus cf. L. awokanak McLaren; x 1; pedicle, brachial, posterior, and lateral views; location 28.

Figs. 41 - 43 — Athyris aquilonius Norris; x 1, pedicle, brachial, and posterior views; location 28.

PLATE 2 .... continued

Figs. 44 - 45 Sieberella? newtonensis Imbrie; x 2; posterior and anterior views; location 28.

Figs. 46 - 49 Schizophoria manitobenesis Whiteaves; x 1; pedicle, brachial, posterior, and lateral views; location 22A.

Figs. 50 - 52 Schuchertella sp.; x 1; pedicle, brachial, and posterior views; location 28.

Fig. 53 Pentamerella sclavus Norris; x 2; lateral view; location 5.

Fig. 54 Stropheodonta sp; x 2.4; pedicle view; location 22A.

Figs. 55 - 58 Spinatrypa hornensis Norris; x 1; pedicle, brachial, lateral, and posterior views; location 28.

Fig. 59 Dechenella sp; x 2; pygidium; location 2.

PLATE II.

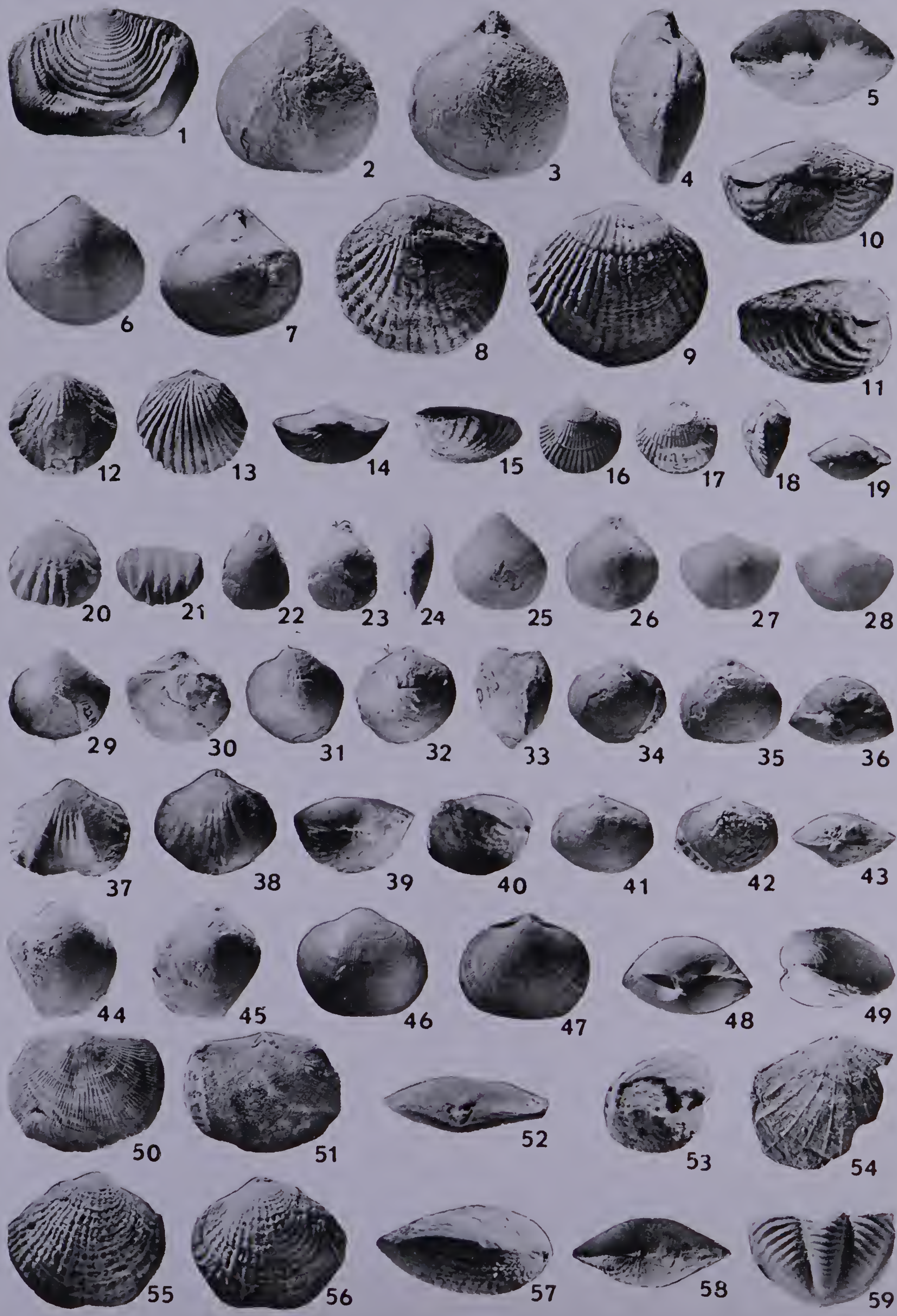
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PLATE 3

Horn Plateau reef corrals

Fig. 1	Sinospongophyllum cf. S. planotabulatum Yoh; x 1.2; longitudinal view; location: Core-hole No. 5, 147 feet.
Fig. 2	Syringopora cf. S. tubiporoides Billings; x 1.2; transverse view; location: Core-hole No. 5, 269 feet.
Fig. 3	Stringophyllum redactum McLaren; x 1.2; longitudinal view; location: Core-hole No. 1, 49 feet.
Fig. 4	Thamnopora limitaris (Rominger); x 0.9; location: Core-hole No. 1, 254 feet.
Figs. 5 &6	ORGANIC CONSORTIUM; longitudinal view; 5) x 1.2; the alga - stromatoporoid Clathrocoilona overlain by Alveolites which is in turn overlain by Chaetetes; location: Core-hole No. 1, 298 feet 6) x 1.2, Clathrocoilona surrounded by Alveolites, location: Core-hole No. 1, 292 feet.
Figs. 7 & 8	Syringopora cf. S rockfordensis (Fenton and Fenton); location: Core-hole No. 3, 221 feet; 7) x 2.2; transverse view, 8) x 1.8 longitudinal and transverse views.
Figs. 9 & 10	Utaratuia cf. U laevigata Crickmay, x 1.8, location 28; 9) transverse views; 10) longitudinal view.
Fig. 11	Hexagonaria n. sp?; x 1.7; transverse view; location: Core-hole No. 2, 150 feet.

PLATE III.

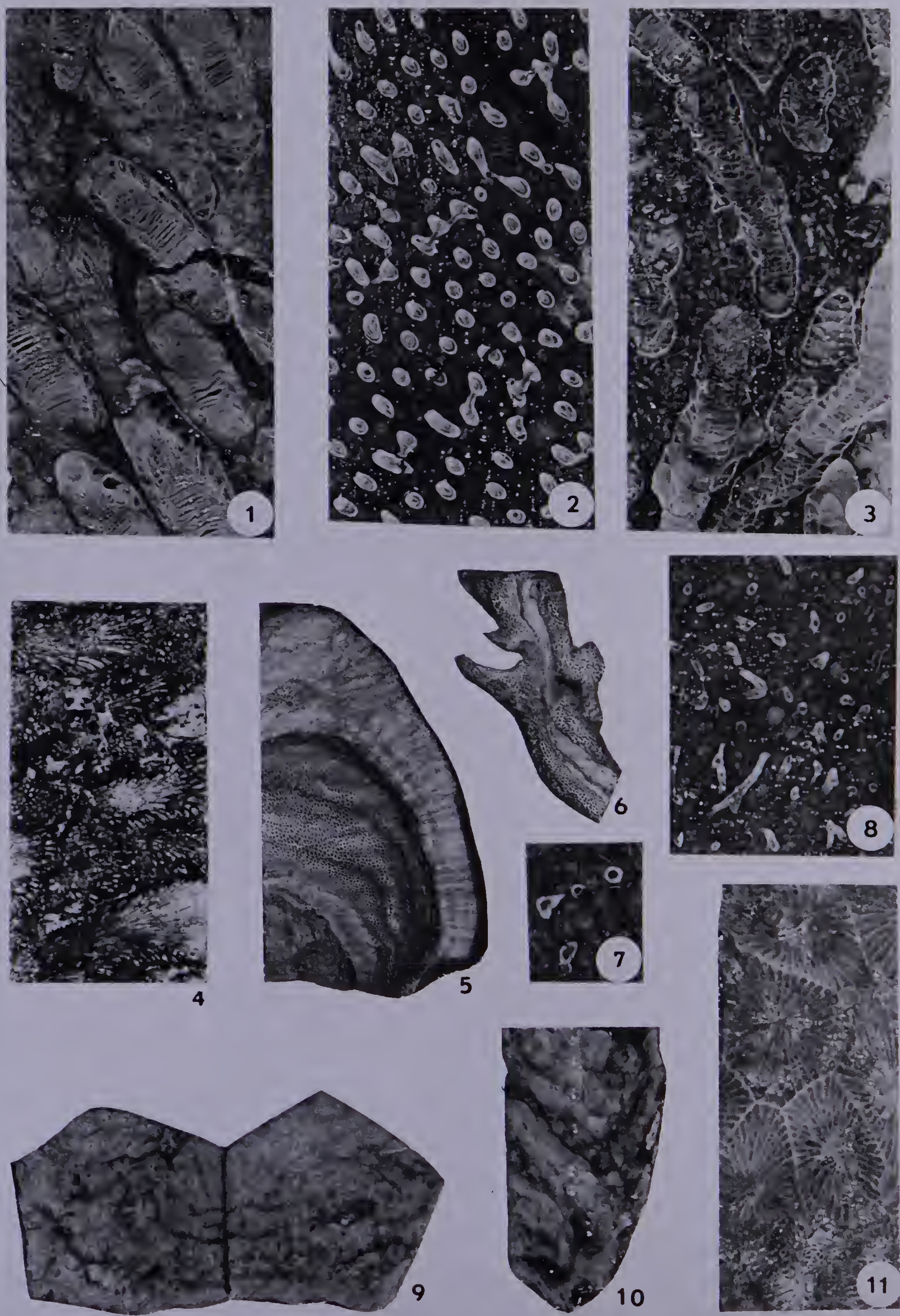


PLATE 4

Horn Plateau reef corals

Fig. 1	Chaetetes sp.; x 7; transverse view; location: Core-hole No. 1 97 feet.
Fig. 2	Favosites alpenensis Winchell x 1, transverse view; location 95.
Figs. 3 & 4	Neostringophyllum craig McLaren; location: Core-hole No. 3, 118 feet.
Figs. 5 & 6	Cyathophyllum greteneri n. var. A., location: Core-hole No. 3, 269 feet. 5) x 1, longitudinal view, 6) x 1.2, transverse view.
Figs. 7 & 8	Alveolites sp.; location: Core-hole No. 5, 270 feet, 7) x 1.3, longitudinal view, 8) x 1.2 transverse view.
Figs. 9 & 10	Disphyllum salicis McLaren, x 1, location 32, 9) transverse view 10) longitudinal view.
Figs. 11 & 12	Alelophyllum nebracis McLaren, location 12, 11) x 1 transverse view, 12) longitudinal view.
Figs. 13 & 14	Favosites irosculis; location 52, 13) x 1 transverse view, 14) x 1.4, longitudinal view.
Fig. 15	Disphyllum golfussi (Geinitz); x 1, longitudinal view; location 83.
Fig. 16	Buschophyllum? sp; x 10; longitudinal view; location 37A.
Figs. 17 & 18	Australophyllum? cf. A? thomasae (Hill and Jones); location 89, 17) x 1.6, longitudinal view, 18) x 1.3, transverse view.
Figs. 19 & 20	Cystiphylloides spinosum McLaren; location 41, 19) x 1.5, longitudinal view, 20) x 1.7, transverse view.
Figs. 21 & 22	Heliophyllum borealis McLaren; x 1; location 22A; transverse and longitudinal views.

PLATE IV.

PLATE 5

Horn Plateau reef fossils

Fig. 1	ALGAL ENCRUSTRATIONS? on crinoid grains. These are overlain by the stromatoporoid Euryamphipora? sp.; x 25; location: Core-hole No. 1, 15 feet.
Fig. 2	LACE - LIKE ALGA grain; x 50, location 21.
Fig. 3	ALGAL STRUCTURE?; x 50, location 21.
Figs. 4 & 5	CALCISPHERES; x 160; 3) two walls, location 2; 4) one thick wall; location: Core-hole No. 1, 237 feet.
Fig. 6	MASSIVE ALGA grain; x 25; location 4.
Fig. 7	ALGA TUBE; x 25, location 4.
Fig. 8	DENSE ALGA grain; x 25, location 24.
Fig. 9	GLOBULAR ALGA grain; x 50, location 2.
Fig. 10	Sphaerododium? sp.; x 50; location 2.
Figs. 11 & 12	SPONGE - LIKE ALGA grain showing distinctive tabular and cellular parts; x 25, location 24.
Figs. 13 & 14	Ceratopea? sp.; x 1, location 23.
Fig. 15	Platyceras sp.; x 1, location 40.
Fig. 16	Straparollus sp.; x 2; location, Core-hole No. 3, 95 feet.
Fig. 17	Leptodesma sp.; x 2, location 22A.
Figs. 18 & 19	Conocardium sp.; x 2, location 22A.
Fig. 20	Mastigospira sp.; x 1, location 40.
Fig. 21	Gasterocoma?; x 10, location: Core-hole No. 3, 357 feet.

PLATE V.

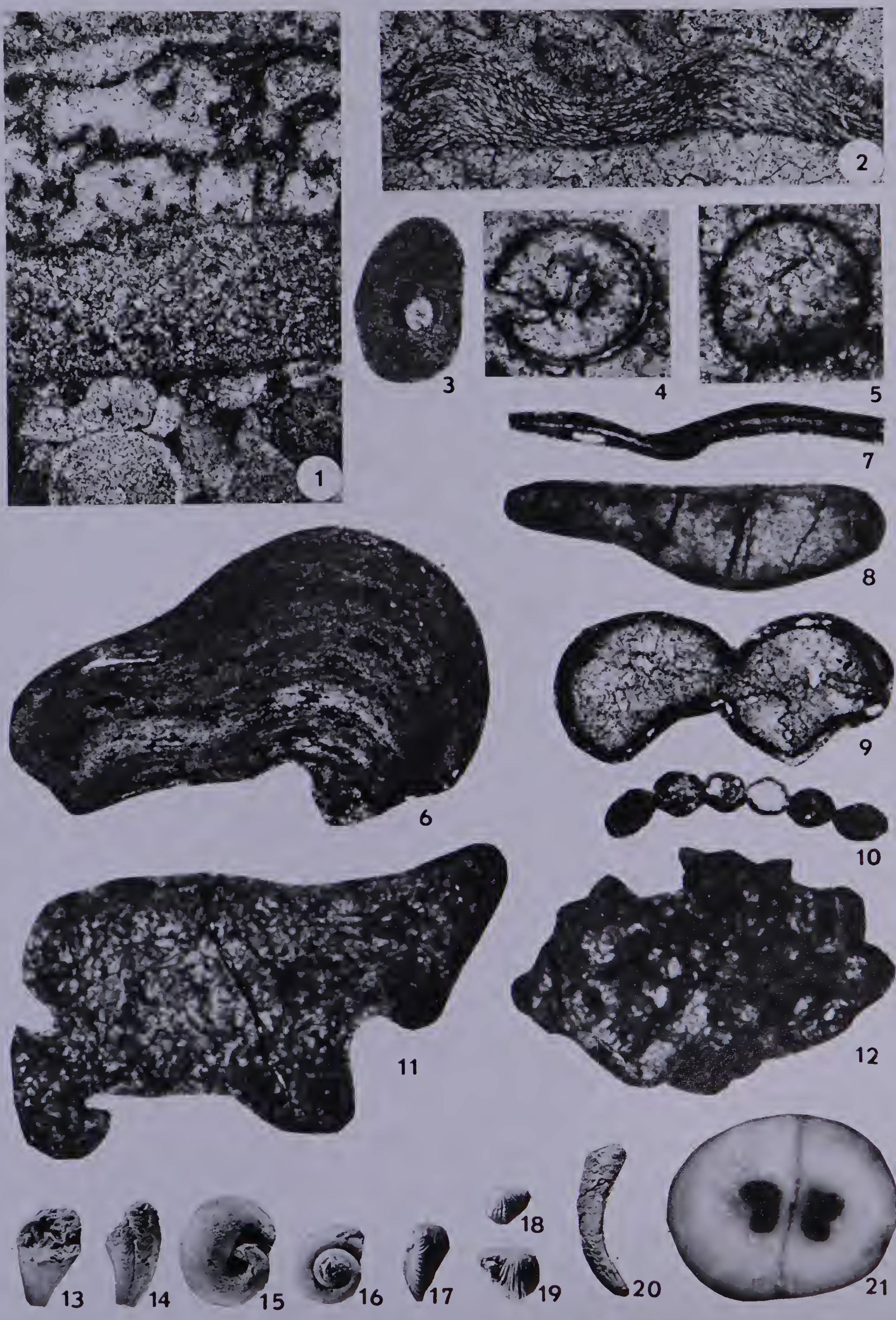


PLATE 6

Horn Plateau reef stromatoporoids

Figs. 1 & 2	_Trupetostroma_ cf. _T. kakisaense_ Stearn; location: Core-hole No. 2, 213 feet; 1) x 2.2, longitudinal section, 2) x 2, tangential section
Figs. 3 - 5	_Stromatopora_ sp.; 3) x 0.8; location: Core-hole No. 1, 320 feet; vertical section; 4) x 2.2; location: Core-hole No. 1, 328 feet; vertical section; 5) x 2.2; location: Core-hole No. 5, 220 feet; tangential section.
Figs. 6 & 7	_Parallelopora_ sp.; location: Core-hole No. 1, 70.5 feet; 6) x 2.3; tangenial section; 7) x 2; vertical section.
Figs. 8 & 9	_Clathrodictyon_ sp.; location 52; 8) x 2.3; vertical section; 9) x 2.2; vertical section.
Figs. 10 & 11	_Actinostroma_ sp.; location: Core-hole No. 5, 108 feet; 10) x 2.1; tangential section; 11) x 2.4; vertical section.
Figs. 12 & 13	_Clathrocoilona_ sp.; location: Core-hole No. 1, 289.5 feet; 12) x 2.3; vertical section; 13) x 2.4; tangential section.

PLATE VI.

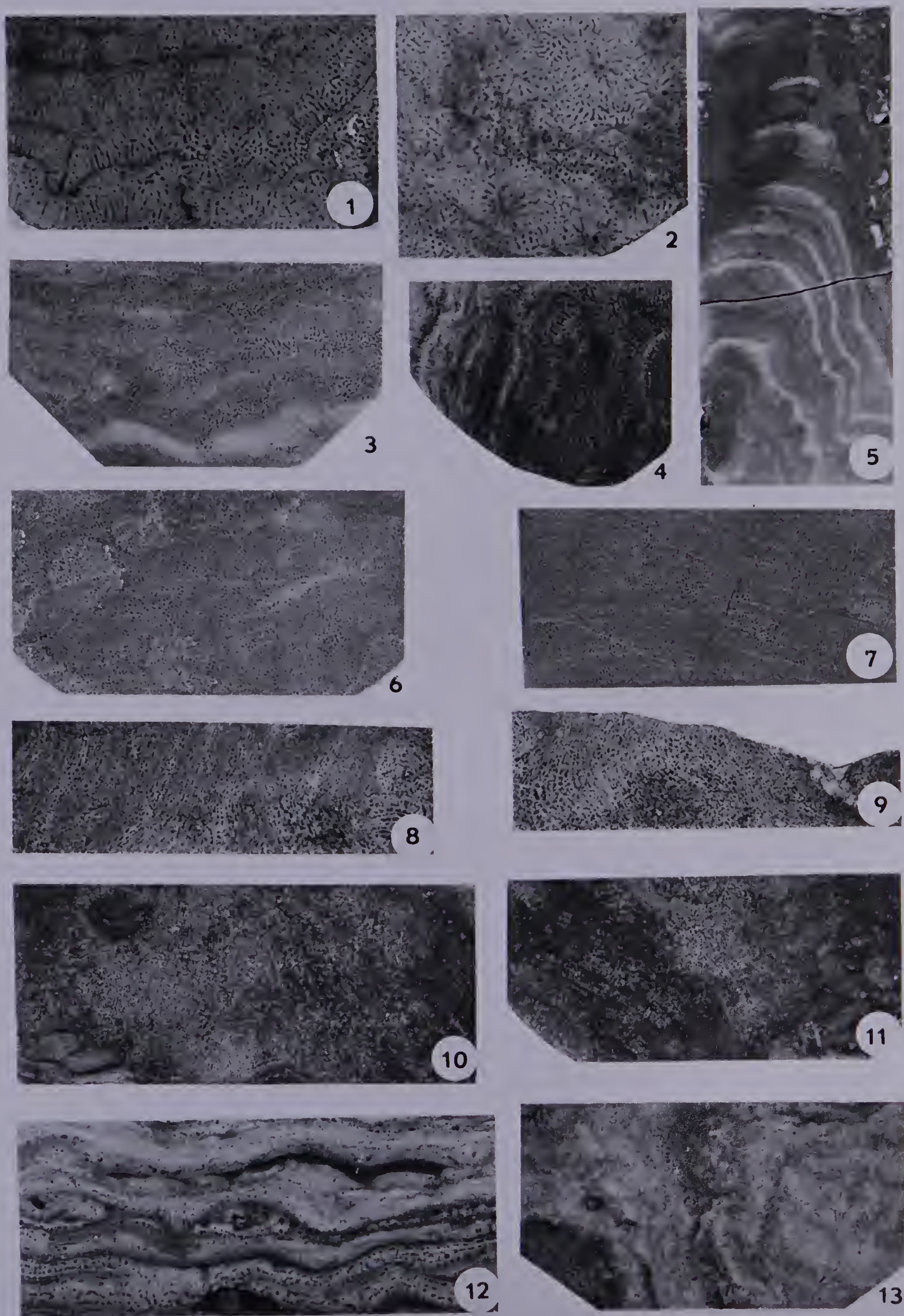


PLATE 7

Stromatoporoids, microfacies, and miscellaneous features

Figs. 1 & 2	Atelodictyon sp.; location: Core-hole No. 1, 78 feet; 1) x 8.3; tangential section; 2) x 5.7; vertical section.
Figs. 3 & 4	Trupetostroma sp.; location: Core-hole No. 2, 143 feet; 3) x 2, vertical section; 4) x 1.8, tangential section.
Figs. 5 & 6	Hermatostroma sp.; location: Core-hole No. 3, 215.5 feet, 5) x 2.5, tangential section; 6) x 2.8 vertical section.
Fig. 7	Stachyodes sp.; x 1.4; tangential section; location, Core-hole No. 5, 74 feet.
Fig. 8	FRACTURE FILLING. Argillaceous lihtoclasts 'floating' in sparry calcite; hand sample; x 0.8; location: Core-hole No. 1, 217 feet.
Fig. 9	CRINOID-CORAL CALCIRUDITE MICROFACIES; Reef flank macrofacies showing large crinoid particles; hand sample; x 1.3; location: Core-hole No. 4, 263 feet.
Fig. 10	STROMATOPOROID DEBRIS. Stachyodes and other stromatoporoid material; hand sample; x 1.3; location: Core-hole No. 3, 324.5 feet.
Fig. 11	PELLETS. x 1; thin section; location 30.
Figs. 12 & 13	BRACHIOPOD CALCRUITE MICROFACIES. Brachiopods in a micritic matrix; hand samples; 12) x 1.3; location, 16A; 13) x 0.8; location 32.
Fig. 14	CRINOID CALCARENITE MICROFACIES showing laminae of black hydrocarboneous material; hand samples; x 1.3; location Core-hole No. 5, 128 feet.

PLATE 7 .... continued

Fig. 15 CONTACT of black argillaceous breccia unit and biolithite (dip of approximately 75 degrees); hand samples; x 1.3, location, Core-hole No. 1, 65 feet.

PLATE VII.

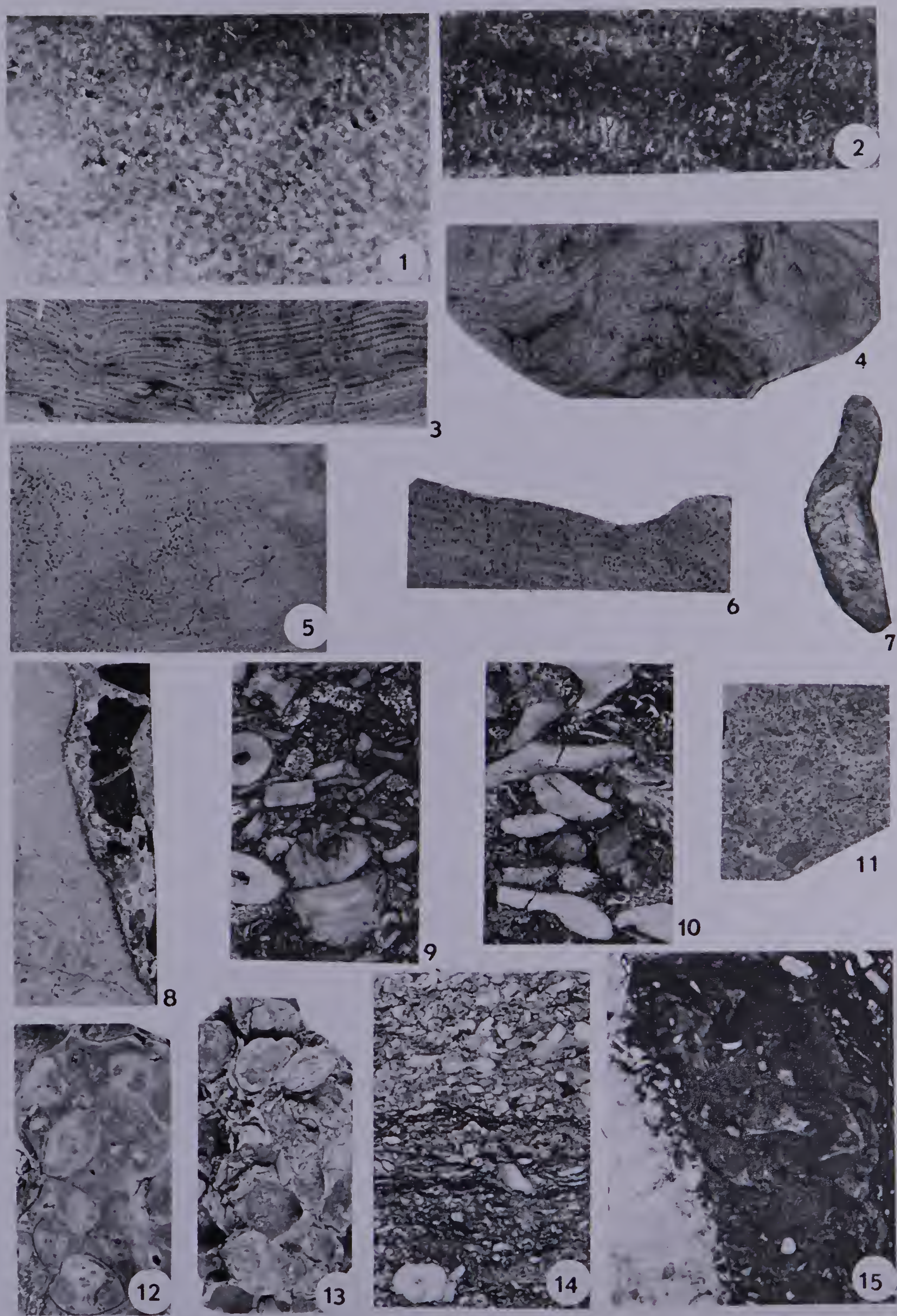


PLATE 8

Horn Plateau reef microfacies

Fig. 1 BASAL CALCILUTITE. Micritic rock interpreted to be the reef foundation; hand sample; x 1.4; location, Core-hole No. 3, 357 feet.

Fig. 2 THAMNOPORA BIOLITHITE. Organic reef macrofacies, *in situ* *T. limitaris* has acted as a sediment baffle entrapping micritic material. Dark areas surrounding the coralla are translucent sparry calcite; hand samples; x 1.3, location, Core-hole No. 1, 270 feet.

Fig. 3 CRINOID-CORAL CALCIRUDITE. Reef flank macrofacies; crinoid and coral 'rubble' material; hand sample; x 1.3, location, Core-hole No. 5, 160 feet.

Fig. 4 CRINOID THAMNOPORA CALCIRUDITE. Reef Flank macrofacies; gravel sized crinoid and *Thamnopora* material; hand samples, x 1.3; location, Core-hole No. 4, 256 feet.

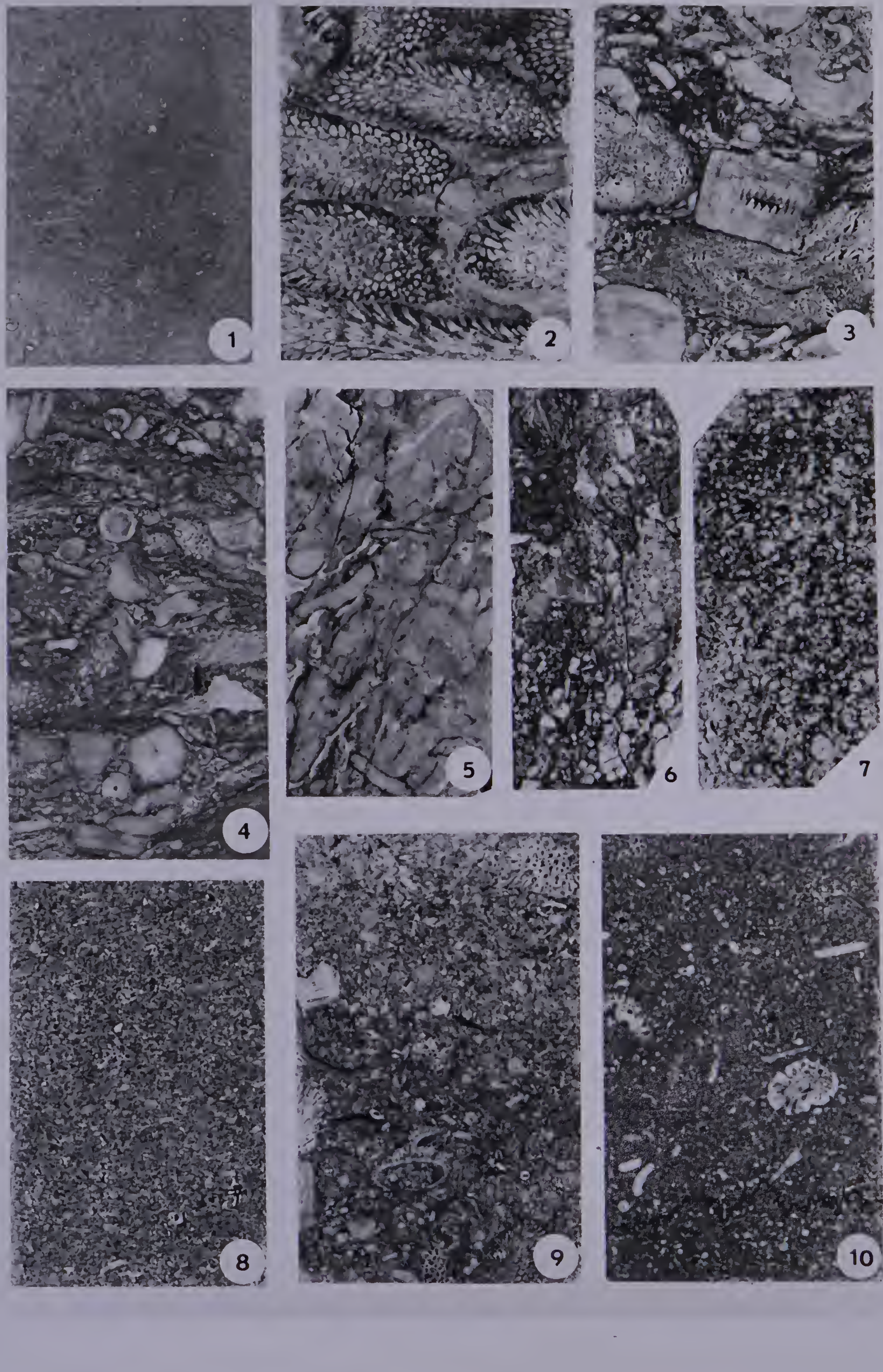
Fig. 5 STACHYODES CALCIRUDITE. Reef flat macrofacies; *Stachyodes* surrounded by micrite; hand sample; x 1.2, location 29.

Fig. 6 RUDACEOUS CALCILUTITE. Reef flank macrofacies, vari-sized skeletal material surrounded by micrite; hand samples; x 1.2, location 76.

Figs. 7 & 8 CRINOID CALCARENITE. Reef flat macrofacies; crinoid ossicles cemented with sparry calcite; hand samples; 7) x 1, location 41; 8) x 1.3; location, Core-hole No. 5, 161.5 feet.

Figs. 9 & 10 CRINOID SKELETAL CALCARENITE. Reef flat macrofacies, crinoid ossicles and other skeletal material; hand samples, 9) x 1.3; location, Core-hole No. 5, 215.5 feet; 10) dark brownish grey variety; x 1.3; location, Core-hole No. 3, 337 feet.

PLATE VIII.



APPENDIX A

HORN PLATEAU REEF CORE-HOLE DATA
PAN AM FAWN LAKE CORE-HOLE NUMBERS 1 TO 5

CORE-HOLE	ELEVATION		HORN RIVER FORMATION			HORN PLATEAU FORMATION			TOTAL DEPTH	
	Reef [1]	Regional [2]	Depth	Elevation	Thickness	Depth	Elevation	Thickness [4]	Depth	Elevation
1	- 1.8	879				1 [3]	878	331	336	543
2	-52.4	829	6	823	122	128	701	114	232	597
3	-49.7	831	8?	823	24	32	799	314	358	473
4	-63.0	818	10	808	234	244	574	56	300	518
5	-68.0	813	14	799	36	50	763	220	270	543

(1) The reef elevation was obtained by plane tabling. The common centre of the radial lines (Fig. 2) was established as the "zero" value reference point.

(2) The regional elevation of the reef "zero" value is approximately 881 feet above sea level. This was established by using a value of 635 feet for Fawn Lake (Army Survey Establishment Provincial Map 85K, 1958) and adding 246 feet, the difference in elevation between the reef and Fawn Lake obtained by helicopter altimeter.

(3) 1 implies that there is 1 foot of overburden.

(4) Thickness is the amount of reefal material cored and does not indicate formational thickness.

APPENDIX B

REGIONAL WELLS USED IN PRESENT STUDY

WELL(1) LOCATION	G L	K B	T D	S S V(2)	LONELY BAY FORMATION ELEVATION	LONELY BAY FORMATION S S V(2)
A-21#5	610		1375	765	704	94
A-36#7	609		665	56	538	+71
A-50	700	707	1867	1167	1370	670
A-66	824	830	1870	1046		
B-29#4	616	622	1000	384	843	221
C-25	726	732	1581	855	1078	352
D-73#19	565	571	1820	1255	1377	812
D-74#6	602		712	110	581	+21
G-41	684	691	1651	967	1243	559
G-61	835	841	1000	165	790	+45
G-68#8	624		1276	652	517	+107
G-71	542	549	1429	887	1000	458
H-27	709	716	1708	999	1368	659
I-47	513	520	1511	998	1096	583
K-13#11	646		540	+106	350	+296
M-2#1	659	665	1424	765	900	241
M-16	802	808	1681	879	1185	383
M-39	697	703	1425	728	976	279
N-54	820	827	1780	960	1349	529

Appendix B ....Continued

WELL[1] LOCATION	G L	K B	T D	S S V[2]	LONELY BAY FORMATION ELEVATION	LONELY BAY FORMATION S S V[2]
0-15#23	731	737	1957	1226	1527	786
0-16#2	680		947	267	848	168
Imp. Triad Davidson Crk.	2073	2086	2737	+664	1714	+359
Imp. Triad	2425	2438	3223	+798	2078	+347

(1) Locations refer to the C.S. Laferte River Wells except for the last two.

(2) Values are negative unless otherwise indicated.

G L = Ground Level, K B = Kelly Bushing, T D = Total Depth,

S S V = Sub Sea Value